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SIXTEENTH NATIONAL POTATO UTILIZATION CONFERENCE REPORT

FORT COLLINS, COLORADO
JULY 27-29, 1966

AGRICULTURAL RESEARCH SERVICE
UNITED STATES DEPARTMENT OF AGRICULTURE

THE SIXTEENTH NATIONAL POTATO UTILIZATION CONFERENCE was held in conjunction with the Fiftieth Annual Meeting of the Potato Association of America during the week of July 25, 1966, at Colorado State University, Fort Collins, Colo. The meetings of the Potato Association of America were held July 25 and 26. The papers presented have been printed in various issues of the American Potato Journal. The papers included in this report were given at meetings of the Potato Utilization Conference on July 27 and 28.

On July 29 and 30 interested participants toured the potato-growing areas of the San Luis Valley. This tour included a review of the activities of the San Luis Valley Potato Research Center at Alamo, Colo. Sponsors of the Utilization Research Conference were:

The San Luis Valley Potato Administrative Committee
United Fresh Fruit and Vegetable Association
Colorado State University
United States Department of Agriculture

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Numbers in parentheses refer to literature cited at the end of each paper. The literature cited, figures, and tables are reproduced essentially as they were supplied by the writer of each paper.

This report was prepared in the Western Regional Research Laboratory, U.S. Department of Agriculture, Albany, Calif. 94710, headquarters of the Western Utilization Research and Development Division of the Agricultural Research Service of USDA. Copies are available on request.

February 1967

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NATIONAL POTATO UTILIZATION CONFERENCE

POTATOES IN MID-1966

Floyd F. Hedlund, Director
Fruit and Vegetable Division, Consumer and Marketing Service, USDA
Washington, D.C.

We are now gathered at the 16th National Potato Utilization Conference--and 16 years is not a ripe old age for either an individual or an institution. But, in a short span of time, these conferences have come a long way. They have provided stimulation and challenge to all aspects of the potato industry. But nothing in this world is static.

The world continues to move toward bigness. The persistent movement toward dominance of large-scale, formal organizations is the most apparent single economic trend in our society in this century. As a result, we have moved toward greater interdependence, centralization, formality, and impersonality. One consequence is that individuals and organizations are subject to the influence of forces of wider and wider scope.

Ours is an expanding and prosperous economy. Nationally, we are now in our sixth successive year of economic expansion. Current projections suggest that the gross national product (GNP) for 1966 will exceed $727 billion, a new alltime high. This is about 8 percent more than the $676 billion GNP of a year ago, which also was an alltime high. And our population continues to grow. Projections suggest that U.S. population will cross the 200 million mark by late 1967--a little more than a year from now.

Farmers have continued to gain efficiency. With modern equipment and know-how, the U.S. farmer has doubled his output per man-hour in a little over 10 years. One man on the farm today does all the work that was performed by four in 1939. In fact, during the post-war period, productivity per man-hour in farming has increased at twice the growth rate of output per man-hour in other segments of our economy.

The process of marketing the farmer's produce--in which we share a common interest--is also gaining in efficiency. It has become a vast sector of our economy. Helping to make this vast and changing marketing process flow in an orderly and efficient manner is an important job of the U.S. Department of Agriculture and the Consumer and Marketing Service. Our mission, very briefly, is to service the marketing system, to improve and promote it.

Today, the food industry is the biggest business in this country. Sales in food stores in the United States in 1965 reached the $71 billion level. This is $3.6 billion, about 5 percent more than a year earlier. But the number of food stores handling this volume of sales declined by 1,000 in number from 1964. Or, if you prefer, another comparison to get a longer term trend picture, these 227,000 stores in 1965 were 83,000 fewer than 10 years earlier. The average food store sales increased by $153,000 in the 10 years from 1956 to 1965. Of these 227,000 stores, 14 percent were supermarkets compared with only 6.7 percent in 1956. Supermarkets' share of total grocery sales was 71 percent in 1965 and only 52 percent in 1956.

According to the PROGRESSIVE GROCER of April 1966 , "supermarket mergers in 1965 saw nearly 400 food stores change hands in multistore transactions. This is twice as many as changed hands the previous year, but only half as many as in 1955 when an estimated record of 800 supers got new owners."

Mergers have not been confined to the retail food stores. Farmers have been expanding operations. Between 1954 and 1959 we saw a decline in the number of farms growing potatoes of nearly a million, a decline of 52 percent. Preliminary, but incomplete, census data for the 1964 Census of Agriculture indicate that this trend is continuing. In fact, it is beginning to appear that the number of farms growing potatoes may have declined by roughly 50 percent in the 5-year period between 1959 and 1964, while the acreage remained essentially the same and the production increased slightly. Bigness appears to be the trend in potato production as well as in other phases of the economy.

The swing to processing in the potato industry is continuing. New plants have been constructed in Washington, Idaho, and Michigan. Construction of a new dehydration plant has just been started in Colorado's San Luis Valley. Expansion of existing plant facilities has been going on simultaneously with new plant construction, particularly in Maine and Idaho. For the second successive year, the frozen pack of potato products has exceeded 1 billion pounds. The 1965 production was almost 1-1/4 billion pounds. Mergers in this segment of the potato industry are occurring, too, as you well know.

Potato chips and shoestring products continue to be the major processing outlet. The utilization report for the 1965 crop is not yet available, but the chippers used 28.8 million hundredweight of potatoes from the 1964 crop, 12 percent of the total production. Some of these potato chip manufacturers also have been merged into, and have become divisions of, larger organizations.

It is against this backdrop that I would like for us to look at the 1966 potato picture. But, before we do that, I think we should review briefly what has gone before.

The past 2 years have been very unusual in the potato business. The 1964 potato crop was not the smallest crop on record, but it sold at the highest prices in potato history. It sold for $756 million, which set another new high for the value of a potato crop. Truly, 1964 was a bonanza for those who had potatoes to sell. But consumers complained long and bitterly about potato prices and the product.

Carryover supplies from the 1964 crop on January 1, 1965, totaled only 95 million hundredweight, the smallest since 1957. The frozen french-fry holdings also were comparatively small. And the 1965 winter crop was light. The combined early and late spring crops were more than 20 percent larger than in 1964 and larger than average, with several thousand carloads of the late spring crop in California reportedly contracted to Idaho potato processors and to potato chippers. The spring crop was later than normal, and yields were below average in a few key areas--especially California, Arizona, and in Alabama--which kept production below expectations. The summer crops in 1965 were below average, but the fall crop was big, one of the larger fall crops on record.

On the whole, prices held up reasonably well. Some price weaknesses developed with the summer crop, but this cleared up in a matter of a few weeks. The Red River Valley crop was a large one; but, following excessive rains during the harvesting season, shrinkage was heavy. And, during the marketing season of both summer and fall crops, the chippers had difficulty getting the desired supplies and were actively bidding for available stocks of good chipping quality. For whatever reasons, the potato market was good.

Just what happened in 1965 has had potato price analysts doing more than just scratching their heads. Historical data suggested lower prices than were actually realized. Was this a carryover influence from the level of prices in 1964, or was it due to excessive shrinkage? Was it due to heavy processor requirements? Was it because growers were so well heeled financially following 1964 prices that there was no inclination on their part to panic, to sell potatoes in desperation, or to meet bank notes or other obligations? Was it because of the location of potato stocks in which Eastern supplies were a little short and, therefore, the surplus was in the West, somewhat remote from the larger population centers? Or, was it because the demand picture for potatoes has changed? I am not sure that we will know

all the answers to these questions for some time. Certainly processing played an important part. With light storage holdings at the beginning of the 1965 season, processors began earlier than usual to rebuild inventories, as well as to meet increased demand requirements for the processed products. Disappearance of frozen French fries alone in 1965 totaled almost 1 billion pounds--980 million pounds to be specific. And the chipper orders, especially for good chipping quality, went begging through much of the fall crop marketing season. Dehydrated potato products were also in demand.

On the other hand, preliminary data indicate that the per capita consumption of potatoes for food, in all forms, was 102.6 pounds in 1965. This was 8 pounds less than in 1964 and 9.5 pounds less than in 1963. Also, the quality of the fresh potatoes offered consumers from the 1964 and early 1965 crops created unrest and resistance which is likely to be remembered for a long time.

We started the 1966 season under considerably different circumstances. Storage holdings on January 1, 1966, of a little more than 123 million hundredweight, were the largest January holdings since 1962, and 28 million hundredweight larger than a year earlier. Frozen french-fry storage holdings also were larger. We had 314 million pounds in storage on January 1, 1966, some 90 million pounds more than a year earlier; and frozen french-fry inventories continued to climb, month by month, through April. On May 1, 1966, inventories reached 468 million pounds--an alltime record.

Production in the 1966 winter and spring seasons was substantially larger than in 1965, but these seasonal crops continued to move to market at generally good prices through the early spring crop. The late-spring acreage was only slightly larger than in 1965. It was not until the late spring crop started moving to market that substantial price declines developed.

The early summer potato acreage this year is about 11 percent larger than in 1965 and is estimated to produce a crop about 16 percent larger. The late summer and fall acreage is estimated to be about 2.5 percent larger than in 1965. With average yields, the combined late summer and fall potato production should be about the same as in 1965. Don't forget that this will still be a very large potato crop. And a large Canadian crop is expected.

We anticipate that the demand for potatoes for both fresh and processed use will continue strong to meet domestic needs and to supply potatoes and potato products for military and normal export purposes. Fresh market use should continue the trends of the past few years, with per capita consumption of potatoes for

food in all forms expected to recover to about the 110-pound level. Export requirements, principally to Canada, probably will return to more normal levels. Typically, exports to Canada about equal imports from Canada.

The major differences between the 1966 and 1965 crops thus far have been (1) the large carryover stocks on January 1, 1966, some 28 million hundredweight larger than the previous year, (2) the large holdings of frozen potato products which on June 1 were some 190 million pounds, or 75 percent more than the previous year, (3) reduced opportunities in prospect for 1966 fall crop exports to Canada, and (4) prices which have been less than half those prevailing in 1965.

There is an old saying in the potato industry that no 2 marketing years are alike. Even though the 1966 crop is expected to be about equal in size to the 1965 crop, there are enough differences in circumstances to suggest that the marketing season may provide somewhat different results.

As the marketing season approaches for the 1966 late summer and fall crops, I want to stress four important points that, in my opinion, stand out in the marketing of potatoes in the recent past: (1) There is a premium on packaging of preferred grades and sizes of potatoes (2) There is enchantment in convenience (3) Ingenious innovations can pay off in potato marketing, as with other commodities, in returns to the individuals who can read accurately and respond to consumer desires (4) Production and marketing of potatoes, like all other commodities, continue to move toward bigness.

Market News reports consistently show substantially higher prices for preferred grades of potatoes packed to narrow size ranges. Studies indicate that the ultimate consumer is willing to pay premiums for preferred grades and sizes.

Ours is an affluent age with emphasis on convenience. We all insist on it--in home appliances, in automobiles, and in just about everything. Shopping and food preparations are no different. The shopping chore of selecting desired items with a limited budget from among an average of 7,000 to 8,000 items in the typical supermarket is quite a problem to many housewives. Suppliers who make the shopping and food-preparation job more convenient have found it profitable. There is enchantment in convenience for the housewife.

Innovation is change--a new way of doing things. Throughout time, the right and the timely innovations have paid off. Those who have the ingenuity for innovation, whether in marketing potatoes, mouse traps, or what-have-you, must have the ability to read

accurately, and respond to customer desires. Customers are alike in that they like change--something new and something different. They are different in that they do not necessarily all like the same changes. So, innovation requires ingenuity.

The production and marketing structure continues to move toward bigness. As the economist might say, technology of production and marketing continues to push the point of diminishing returns farther and farther out on the scale. It seems to me that these are facts of life that loom into very great importance in the constant struggle for survival for any industry group. Potatoes are no exception. This deserves careful thought and study as to the best course of action for the good of the potato industry.

In this connection, I am going to repeat, for emphasis, some thoughts I have expressed on other occasions. It seems to me that our marketing system is committed to the mass merchandising, supermarket type of operation. With this, there follows the concentration of buying power into fewer and fewer hands. Association with it, but not necessarily a part of it, is the trend toward integration of growing, processing, and marketing operations. The grower's position, as these tendencies continue to develop, will depend heavily on his ability to adjust to the changing conditions and to take advantage of his new opportunities. I am a firm believer in grower-owned and grower-controlled marketing operations, cooperative or otherwise, that assure him a voice in, and a share of, the returns from the processing and marketing of his production.

If a grower is not big enough to provide a continuous, uniform supply of the grades, sizes, and packages required in the mass merchandising business, he might well join with other growers in some form of business enterprise that will give him these advantages of scale. Failing in this, he can associate himself with an established marketing outlet through which these advantages of concentrated centralized sales can accrue to his benefit.

We are all facing the shifting winds of change. No matter what our occupation, our geographic location, or our special interest, all of us are profoundly affected by the changes and challenges of our complex and intricately interrelated system of marketing. We cannot turn back the clock to a simpler day when the marketing system was--or so it seemed--more orderly and easily defined. Leadership was never more necessary than now. I am confident that the human mind is capable of designing its institutions and its conduct to fit its standards of life and freedom.

WHAT DOES THE FUTURE HOLD FOR FRESH POTATOES?

Robert J. Matheison, Division Manager
Safeway Stores, Inc., Oakland, Calif.

National organizations are doing a great service by joining hands in an effort to improve marketability of agricultural products. My own organization is especially interested in fresh potatoes, as well as processed. Knowledge and skills in marketing fresh potatoes are important, although they are not always applied as they should be.

Harvesting and packaging are an area where producers and distributors can join hands in self-help major efforts, rather than going it alone. The National Association of Food Chains and United joined in work on improved containers and have practically eliminated the damage through bulge packing of lettuce. Next, we tackle celery, cantaloupes, and potatoes. Years ago our company made a $15,000 grant to the University of Idaho to ferret out potato damage. Much light was shed but on April 1966 a poll of our field buyers from Maine to Mexico brought back almost unanimous pleas for reduction of handling damage.

Cutting, nicking, bruising, air checking due to mechanical harvesting, and massive storage all damage potatoes. Our buyers suggest prewarming to minimize air check and bruise drops, removing exposed metal edges on conveyor lines, and improving storage temperatures. Mechanical injury to potatoes is still the No. 1 problem, followed by air checking, greening, and internal defects (some due to external bruising, others to field conditions).

The permitted tolerances for US One potatoes are 6 percent for external defects, 5 percent for internal discoloration, and 3 percent for undersize. This totals 14 pounds of potentially unmerchantable potatoes out of every 100. Dump them on a bulk display and Mrs. Housewife grades them out, for she recognizes no tolerance--so by the evening rush hours--only cull outs are on display. Does that help the industry?

As another example, in May 1966, our Washington, D.C., Pre-Pakt Plant had Maine potatoes in 50-pound paper that packed out US One 85-1/2 percent, Two's 2.00 percent, culls 12-1/2 percent <u>although all were paid for at US One A price</u>. Unloading labor was increased 23 percent. Dumping labor increased 33-1/3 percent. The paper bags created a disposal problem and had no resale value. Had these potatoes packed out 95 percent US One, the 600,000 pounds packed would have shown a $1,100 profit, rather than a $900 loss.

We have some specific recommendations that express the consensus of our plant managers:

1. Expedite handling of fresh market stock potatoes in bulk cars and trucks.

   a. Petition carriers for realistic rates on bulk loads based on 6,000-pound minimum.
   b. Petition carriers for construction of additional bulk handling equipment.
   c. Suggest shippers prepare for proper loading of bulk equipment ahead of time.
   d. Increase use of palletized bin shipments wherever and whenever practicable.

2. Upgrade USDA inspection standards to be more meaningful and realistic.

3. Improve equipment for harvesting, processing, and handling of potatoes to cut down mechanical damage.

4. Continue and expand the search for improved varieties of fresh market table stock potatoes.

5. Expand programs where potato industry seeks to increase consumption of FRESH potatoes through advertising, promotional ideas, etc. Again vision the impact of "Look Ma--No Calories" or a similar slogan about nutritious tubers.

The goldmine of cost reduction (material handling) is being tapped as fruit and vegetables are being harvested and stored in palletized bins, and thence through the packing shed and all the way through the distributive pipeline, with container and labor savings at every step of the way. Some Colorado potato growers have semiautomatic bin fillers which mean less labor, a smaller crew as sack fillers, and elimination of sewers and the sacks. Bins are 40x48x62, hold 2,300 pound net. Tare is 200 pounds; 18 bins load a 40-foot trailer. Loading and unloading costs are reduced by two-thirds. There is less fresh bruising, better inspection, less storage space, and cleaner operation. In another field, Mexican tomatoes in lugs are being shipped on expendable pallets successfully to our processing rooms in Canada and the U.S.

Six years ago the most dramatic and fascinating evolution from guerrilla warfare between management and labor into M & M (mechanization and modernization)--and humanization, too--was carved out of the sheer granite of man's resistance to change by the Pacific Maritime Association and the International Longshoremen's Warehousemen's Union.

Longshoremen fought mechanization and innovation every step of the way, because they were defensively fighting the devastating fear of insecurity. In 1942 the transition from raw sugar handled in jute sacks one at a time to bulk loading and unloading increased

productivity per man-hour 6-1/2 to 1, but it also loomed as the first awesome threat to stevedores' jobs, while management at the same time was desperately trying to cope with spiraling labor costs that had dried up Pacific Coast shipping to a mere trickle.

The Pacific Maritime Association of shippers, before automating and mechanizing the loading of ships and before containerization, made a pact with the longshoremen's union to set up funds for men replaced by machines that directly cost the employers 29 million dollars, over a 5-1/2 year period. Call it a bribe, but it resulted in labor peace--a 40 percent increase in shipping, a 3 percent increase in productivity, a 3,500 man-increase in the longshore work force. In addition, a longshoreman can retire at 62 with $7,920 and a $115 month pension from this fund. Loading a vessel now takes 850 man-hours versus 11,088 for a 6,500 ton cargo and a ship turns around in 40 hours, rather than 132 hours.

Growers have demonstrated their ability and desire to stay in the technological race, substituting capital for labor, acreage restrictions notwithstanding. Fact is, it's the only way to cope with the year-by-year increases for the hire of 8 fingers and 2 thumbs, plus fringes, etc. So we have cotton and tomato picking machines and in field trial right now an electronic lettuce thinner, a precision seed planter with seeds 2 to 3 inches apart on water-soluble plastic that rolls out in the furrows. The next step can be adding fertilizer and herbicide to the plastic. Forests are being harvested by giant cutters that snip rather than saw, and the felled trees are being moved by bulldozers and helicopters. A research engineer, studying the electric currents that seem to flow through all living things, believes he can, through electric current, cause a fruit tree to drop its ripe fruit, and through the same technique, stimulate tree growth and production, and draw moisture into the tree electrically. He has opened up a new field in biological engineering.

In cooperation with the Washington State Growers and Tectrol, Division of Whirlpool, Safeway Stores participated in Tectrol-controlled potatoes placed in storage on February 7, 1966, and removed them March 25, 1966. Although untreated with sprout inhibitor, the tubers showed no sprouting and were firm, free of decay, and relatively free of thumb-nail checks. Similar experiments with onions (Yellow Fiesta variety) for 46 days indicate their storage life could be extended.

Summary. There is an opportunity to serve our industry through serving the consumer better than we ever have before, for the best way to serve or help ourselves is to help others. We can do this by looking for the mote in our own eye and by trying to see our products and services through the eyes of our customers.

Let's glamorize and publicize the healthful low-calorie potato to the weight watchers and to the new homemakers, because 200 new family units are formed every hour of the day and most of these are young homemakers who look for information, facts, recipes, values, and utility.

Potatoes represent about 25 percent of our total produce business. If we give them the care they deserve, deliver them at prime quality, care for them, rotate them, and promote them for all they are worth, they will remain the backbone of our produce business and more importantly, the backbone of the menu in homes, restaurants, and institutions.

WHAT DOES THE FUTURE HOLD FOR PROCESSED POTATOES

J. L. Baxter, Vice President
Lamb-Weston Co., Portland, Oreg.

My subject today is one about which there is very little specific and reliable information. This probably reflects the relative lack of marketing sophistication on the part of the vegetable processing industry in general and the potato processing industry in particular. It may be that one or two of the largest processors have done enough market research to predict for themselves the future demand for processed potato products. If so, they are understandably keeping the information to themselves. The rest of the industry reacts or overreacts to demands of the moment and the hazy remembrance that somebody once predicted that some day the potato crop would be half processed.

What I will say about the future is largely personal speculation. The future, of course, must be influenced by the past and the present, and here we have some specific information that we can talk about. We know, for instance, that before World War II, processed potatoes used only about 3 million hundredweight, mostly as chips. We know that this represented 1.9 pounds per capita while fresh potatoes were being consumed at the rate of 126 pounds per capita, or 168 million cwt.

We know that during World War II a potato dehydration industry was born, and that directly after the War it died because returning veterans wanted no part of anything dehydrated, and housewives and chefs were afraid their image would suffer if they bought prepared products which cost more than unprepared but saved time and work. Still, for the first time potatoes had been

processed and when cooked correctly they were good. At the same time a few other food products, processed to provide convenience and not simply because they were perishable, began to appear on the market.

In 1946 the first frozen french fries were test marketed; and in 1947 the first million pounds were produced commercially and marketed at retail. This was really the beginning of potato processing for use in the place of fresh potatoes. The first figures I have, are the National Potato Council figures, which Al Merker worked up over the years. They begin in 1940 and then skip to 1949. In 1940 the 1.9 pounds processed per capita was a total of 3,240,000 cwt.: 240,000 as flour, 300,00 in canned hash, stews, and and soups, and 2,700,000 as potato chips.

To indicate the growth that has occurred, I will take three jumps forward with these same figures. In 1949, the dehydration industry was producing not for retail or institutional use but for manufactured products such as canned soups, stews, and hash. The snack market was beginning to come alive and chips were well into their big growth period which didn't flatten out until the mid-1950's; frozen potato products were still an infant industry selling almost exclusively at retail. But even so, in this year per capita consumption of potatoes for processing had gone up to 10.1 pounds and was using 15 million cwt. of the national crop. Fresh was still showing the downtrend that was established earlier with a per capita consumption down to 97.6 pounds, and total consumption down to 112-1/2 million cwt. Frozen and dehydrated were only using 540,000 and 350,000 cwt., respectively, but these are the ones we want to watch.

So now we will jump ahead to 1955. Per capita consumption for processing had doubled to 20.7 pounds at 34 million cwt. Chips had doubled to 24 million hundredweight. Frozen were up nearly 10 times to 4.6 million cwt. and dehydrated up 8-fold to 2.8 million cwt. Fresh was still declining, down now to 83.3 pounds per capita and 98 million cwt.

The final jump forward takes us to 1964, the last year for which we have figures. Now, per capita consumption for processed potatoes has risen in 9 years to 56 pounds with a usage of 69,429,000 cwt. Dehydration has greatly improved its granules, flakes have been on the market for nearly 7 years, and most important of all, sliced, diced, and instant mashed have gone retail with a bang. This retail splurge started when Borden went national with flakes in 1958 and French's stayed right with them by expanding granule distribution to the national market. From then to 1964, such giants as Pillsbury and General Mills got into the act with a full line of dehydrated potatoes, including hash browns, scalloped, au gratin--all in expensive box packaging in

the grocery section of the supermarkets. Package sizes, serving contents, and pricing were helter skelter and chaotic. The sliced and diced were identical to those served the soldiers during World War II and in Korea, but mother was in a hurry to get to the golf course and if she was still queen even though she didn't bake a cake from scratch, why peel potatoes! The interesting thing is that the national brands did the job and at the retail level. The institutional market lagged and very few chain or regional retail brands ever made the grade. All this put the use of potatoes for dehydration up to 11 million hundredweight, or four times that used in 1955.

By now, also, the big burst in the use of frozen potato products had occurred. This took a route totally different from that of dehydration. The marketing swung from almost totally retail in the early days to about two-thirds institutional and one-third retail. The institutional was sold through local distributors by independent producers with very little participation by well-known national grocery firms. The producers used both their own brands and the brands of their customers and expanded capacity so rapidly that price wars developed in 1962 and 1963. Actually, the prices brought about were so low that many institutions gave the product a try. Once an owner gives his chef frozen potato products, he never gets him to use fresh potatoes again. At the retail level again there was little participation by national marketers, with chain brands and some producer brands the dominant feature. There are indications now that retail has moved up to about 40 percent of the market for frozen potato products. If so, it is probably due largely to the very low-price marketing of "B" grade product in 9-ounce boxes and 2-pound and 5-pound poly bags. This product is continually in distress because it consists of short pieces from the institutional pack. Thus, the phenomenal growth of the institutional demand for frozen french fries keeps the retail side of the market automatically and continuously under pressure to dispose of this off-grade material. Grocers are inclined to lead with this product. There is just nothing in the prepared food field to compare in food value and convenience to a 9-ounce box of grade "B" fries at 10 cents or a 2-pound poly bag at 29 cents.

Besides this growth in french fries, we are beginning to notice more and more interest on the part of the consumer, both retail and institutional, in some of the other very good frozen potato products that have been around for quite a while but not widely used. Right now the most popular are hash browns, both shredded and southern style, and potato rounds, a chopped, formed, fried product sometimes called puffs.

All this brings the 1964 usage for frozen potato products up to 20.5 million cwt., about 4-1/2 times that of 1955 and nearly 40 times that of 1949, which seems like such a short time ago to many of us. Fresh potato consumption during the period continued its slump, hitting a base of about 78 pounds per capita in 1958 and continuing at about that level through 1964 when 127 million cwt. were consumed fresh.

I have dealt here primarily with dehydrated and frozen potato products because they are the staples that have shown consistent growth and for which there is probably the greatest opportunity for continued growth. There are others. Potato flour seems to have a basic demand, has grown steadily but still uses only 3 million cwt. of potatoes, and it was on the scene long before the others. Canned also have been around since before World War II but still only use 1.75 million cwt. Hash, stews, and chowders are at 1.5 million cwt. but their probable increase doesn't show up because most processors use dehydrated potatoes, translating growth thus to the dehydrated category. Chips are big, being the biggest single use of potatoes for processing. Their growth has been a remarkably steady 10 percent a year since 1959. This appears to be the pattern, at least for the time being. Frozen and dehydrated usage on the other hand has grown 100 percent in the same period, and so it appears that we should look at dehydration and freezing as the areas of future growth.

If we start with frozen products, we should look first at the institutional market and, of course, ask what percentage penetration has been achieved. I think our estimate would be at least two-thirds nationally and much higher in some markets. If this is so, and we allow 10 percent for those who may never convert, and we now produce around 1.2 billion pounds of frozen, then we have a total market of 2 billion pounds less 10 percent, or 1.8 billion, or around 36 million cwt. of potatoes. This means that based on the present size of the market (and actually the institutional market is increasing faster than the population increase), there is the opportunity for a 50 percent increase in frozen potato products at the present rate of serving, which is said to be 33 percent.

We believe that a substantial amount of the conversion left lies in the drive-in market, which usually serves potatoes only as french fries, as compared to the sit-down market which serves about 33 percent of their potatoes as french fries. We also believe, however, that whereas the growth of frozen french fries institutionally has so far been on a convenience and cost basis, there is now an opportunity to increase that 33 percent through quality improvement, particularly through handling at the restaurant level, and through much more promotional effort aimed at the ultimate consumer.

The greatest opportunity for increase is at the retail level. We believe that only some 10 percent of the potatoes used in households are french fries and probably some 60 percent of these are frozen. It would seem that market saturation in terms of residency in cabinets is just about complete. The problem is to get household usage up to the level of institutional. As far as I know, no one has asked the consumer why he eats french fries three or four times as often when he eats out as when he eats in. If he were asked, I guess we would all expect him to say "they taste better," and this goes back to the difference between the refried institution-served product and the oven-cooked home product. There has been an attempt to bridge this gap with the so-called cold-start method of preparation in liquid oil, but it is not yet widely used either because it essentially is not good or because it has not been sold hard enough.

Other factors at retail are packaging, merchandising, and promoting, which have been unimaginative and second rate at best. The product has been sold on a price basis, and lower prices have been based on lower quality in many cases. The industry really has not been doing a very good job at retail, both as to selling and as to inherent nature of the product. As the industry grows up these things must change if it is to reach full potential.

There is obviously an opportunity to go beyond the 2 billion pound mark, even up to 3 billion, for frozen potato products, but this growth will be much more difficult and require much more sophisticated research, production, and selling than has been accomplished so far. I am sure we will be selling that 2 billion pounds of frozen potato products within 10 years, and the potential for more is there as well.

Dehydrated products are using only half as many potatoes as are frozen. We are told by surveys that mashed potatoes are the most widely used potato product served in the home; for instance, with 34 percent against and 10 percent for french fries. The penetration of that market by dehydrated instant mashed potatoes is probably as low as 20 percent. I do not have figures on the percentage of the mashed used in institutions, but if it is even half that of french fries, the relatively low market penetration of around 30 percent, along with the higher retail potential, leaves room for good growth with this product also.

Again, all is not just right quality-wise. The instant mashed potato is perishable. We know it develops off-flavors in storage. Unless it is very fresh, it has a manufactured taste. It is being sold with considerable vigor at the retail level, and in many cases the packaging is both attractive and expensive. Beyond that, and in store deals and promotions, not much is done to sell the product.

At the institutional level, instant mashed has been overshadowed by the more glamorous frozen french fry but here again there is a much broader market than is being exploited, simply because the selling effort has not really been made. It is possible that with the exception of government demand for troop feeding, the use of dehydrated potatoes will not increase substantially in the immediate future, but with product improvement and better selling, there is unquestionably the opportunity to double the use of potatoes in dehydrated potato products.

In 1940 per capita consumption of processed potatoes was 2 pounds. In 1949 it was 10 pounds. Since 1949 it has increased every year without fail through 1964 when it reached 56 pounds, and 1965 will be no exception when the final usage figures are compiled. The next 10 years will continue this growth for many reasons. One is the continued lack of quality control and merchandising on the part of the table stock industry. Raw potatoes are still poorly graded for size and defects and are frequently unwashed and packaged in a brown paper bag. Internal cooking quality, such as solids content and after-cooking darkening are of no concern to the table stock grower unless he sells to a processor, and he only uses sprout inhibitor for the late, late show. It's not only ridiculous but pitiful and not helped one bit by the chain buyers who still buy this product and pass it along to the American public.

Another reason that goes along with this is the constant improvement in quality of the processed products that are being produced today. It is a manufacturing process--precise and controllable. Competition is tough and it is more and more on a quality basis, so that everybody has to measure up or fall by the wayside.

A third reason is a subtle yet very noticeable change in attitude on the part of the institutional user. Once they resisted. It just didn't seem right to them to use processed potatoes. Now processed potato products are fully accepted. One large drive-in chain that has made a fetish of using raw potatoes tested frozen french fries in one of its best units and asked for a report to headquarters. The answer was three pages on why they should change to frozen, and ended up "Now that I've had 'em I'd rather fight than switch." This means we will convert all the rest of the institutions and when we have them on frozen french fries, hash browns and rounds, dehydrated mashed, diced, and sliced, we'll work up a few more--such as frozen baked, au gratin, chantilly, and rissole, so that they will be at last out of the mess of price and quality uncertainties of using fresh. They will have the ultimate in portion control, cost control, and quality control and a varied menu besides. With unskilled labor as it is

today, they will hurry to get there. The mass acceptance of the processed potato from school lunch to hospital, to the best restaurant, to the drive-in, to the hashhouse is complete. We now just have to determine their needs, develop the products, and get them into the channels of distribution.

Still another reason is the new breed of housewife that is going to be our customer of tomorrow. She's been brought up in this world of convenience foods. She can't bake a cake from scratch and doesn't want or need to know how. She's conditioned to the speed and convenience of prepared foods; and she just isn't going to be bothered with handling raw potatoes. We are going to improve our products for her, we'll package them better, we'll sell them harder, and she's going to buy and buy and buy. The Frozen Potato Products Institute is working on her now with promotional and instructional material supplied in large quantities to the home economics departments in schools.

A final reason is that potato processing is now a huge industry with a huge stake in consolidating its position and progressing. It is becoming more sophisticated in research, quality control, and merchandising. The industry has spent the last 15 years convincing the institutional users and retail consumers that the potato should be accepted as a processed food. This is done. Processing is here to stay. There is now a whole new era ahead--of new and improved products and particularly of new and better selling and merchandising.

At a utilization conference in about 1956, I predicted that some day potatoes for food use would be 50 percent processed. Well, through 1964 we have only reached up to 35 percent, even through our usage has doubled. I am sure that Idaho processed more than 50 percent of its crop in 1965, and that more than 40 percent of the food-use potatoes of the fall-producing States were also processed in that year. So, I am certain now that the 50 percent mark will be reached soon, and that 75% is a reasonable and attainable goal within the next 10 years.

BIOLOGICAL CONTROL OF INSECT PESTS ON POTATOES

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Many species of insect are a hazard to the commercial production of potatoes. In the United States, over 100 species are of economic importance at once place or other or at one time or other though relatively few do serious damage every year. Among those that are potentially or actively an annual threat are aphids (Aphidae), the Colorado potato beetle (Leptinotarsa decemlineata, Say), flea beetle (Epitrix spp.), leafhoppers (Cicadellidae), and wireworms (Elateridae). Present emphasis in the potato insects research program of the Entomology Research Division is concentrated on aphids and wireworms, the two groups presently of greatest importance countrywide or that are most difficult to control.

Insects damage potatoes by feeding on or in the above- or below-ground parts of the growing plants, including the foliage, stalks or stems, tubers or seed-pieces, or roots on or in tubers in storage. Such feeding may reduce the yield or quality of tubers or both. Also the damage may be twofold: the physical condition of the plant or tubers may be seriously impaired or the health of the plant or of its tubers may be affected by viruses or other disease organisms that are introduced when the insect feeds.

Potato processors and many consumers of the "fresh crop" are well aware that tuber quality can be affected by insects. But many, including some potato growers, do not fully appreciate the far-reaching effects on yield and quality of potatoes caused by virus diseases or other organisms introduced by some insects, particularly aphids. Seed potatoes from infected plants grow into diseased plants which may produce small or inferior tubers. Also, when small tubers are not harvested, they frequently overwinter in the soil and produce plants the following summer; if these plants are infected with an aphid-borne virus, they serve as infector plants for aphids which feed on them and then move to and infect healthy plants.

Control with Insecticides

Four basic factors that are difficult to overcome account in large part for the fact that satisfactory control of potato insects with insecticides has been and likely will be a continuing problem. These include (1) increased tolerance or resistance of

certain insects to some insecticides, (2) the variability in effect of the insecticides due to environmental factors, (3) the high degree of insect control required in many instances to prevent or to obtain an appreciable reduction in damage, and (4) the absorption and translocation of some insecticides to the tubers where the harmful residue may rise beyond the established tolerance. A few examples will illustrate the importance of these factors.

Increased tolerance or resistance.--For a number of years the Colorado potato beetle has been difficult to control with insecticides on Long Island, N. Y., and in parts of the Southeast; at times it is more difficult to control in Rhode Island than elsewhere in New England. The potato flea beetle, Epitrix cucumeris (Harris), is affected less by DDT, endosulfan, and other related materials in some sections of the Northeast than in others. Overwintered adults of this beetle require lower doses of some materials to achieve early-season control than summer-generation adults. This is also true of early-season control of aphids. Also lower rates of application of several insecticides are necessary to achieve an acceptable level of control of several pest insects of potato in northeastern Maine than in the Northwest, Midwest, Southeast, or even farther south in New England.

Influence of environment.--Diazinon provides better control of wireworms in some sections of the country than in the colder soils of northeastern Maine. On the other hand, in Maine, higher doses of chlordane appear to be required against wireworms than in many other areas. Endosulfan or, sometimes, parathion provides better control of aphids on warm calm days than on cold windy days. Also higher doses of several materials are required to achieve the same degree of control of some insect pests of potatoes when they are applied to one kind of soil than of another.

Degree of control necessary.--A potato plant can be infected with some virus diseases by one shallow feeding probe of a single viruliferous aphid, leafhopper, or other insect vector. A slow-acting insecticide may thus cause much less reduction in infection, when the virus is carried on the insect's mouthparts, and is spread by a shallow feeding puncture, than when it is carried inside the insect and is spread by deep penetration of the mouthparts into the foliage. K. E. Gibson found that small populations of wireworms caused damage to potato tubers far out of proportion to their numbers; thus small populations surviving an application of insecticide can cause damage far out of proportion to their numbers (J. Econ. Entomol. 32: 121-124, 1939).

Harmful residues.--The possibility of insecticide residues in excess of tolerance is a constant problem. Some materials that are otherwise promising cannot be used as insecticides because of

residues that remain on or in the tubers. Label approval for the use of aldrin was withdrawn because of tuber residues. Also adequate control of some insects with certain materials cannot be achieved because the frequency or rate of application must be limited to avoid the possibility of tuber residues in excess of tolerance.

Research program.--The Entomology Research Division has a continuing program designed to achieve better control by overcoming these four problems; much of this program is performed in cooperation with the State Agricultural Experiment Stations. Other important or associated areas include more effective methods of applying and timing of recommended insecticides, the discovery of materials that are more effective than presently recommended insecticides against the pest insects or that will prevent or inhibit field spread of certain virus diseases when applied to growing plants, and improvements in cultural methods of insect control. Also, studies of the biology and ecology of the pest insects are necessary corollaries in developing the most effective control with insecticides.

Natural Control

Studies of the biology of potato insects have been made in cooperation with the Maine, Washington, South Carolina, and California Agricultural Experiment Stations. For a number of years the studies in Maine and in Washington have emphasized population dynamics and natural control of aphids. We have also attempted to recognize the various biological agents and to assess their importance in the natural control of aphids on potatoes and on other host plants.

In Maine, in a study period of 24 years, about 40 species of parasites have been recovered from potato-infesting aphids. Unfortunately nearly half this number are hyperparasites, that is, parasites of the parasites inside the aphids, and occasionally as many as 35 percent or more of the primary parasites in potato aphids have been killed by these hyperparasites. Although appreciable parasitization of the potato aphid, Macrosiphum euphorbiae (Thomas), has occurred in some years, we have not detected a significant reduction in rate of population increase of this aphid or of three other species of potato-infesting aphids. By this, we do not intend to imply that parasites give little or no control of those aphids; they undoubtedly are of substantial importance in most years.

Among arthropod predators of the aphids, spiders are probably of greatest importance in Maine. Larvae and adults of coccinellids ordinarily have been the most numerous; others were

larvae of chrysopids and syrphids and nymphs and adults of anthocorids. Only occasionally have these predators been sufficiently abundant to reduce perceptibly the rate of aphid increase on potatoes. To reduce significantly the rate of aphid population growth, the mobile stages of predators must be found on about 5 percent or more of the potato plants (judged by examining three leaves per plant--top, middle, bottom).

Entomophthoraceous fungi seem to have been the most important biological aphid control on potatoes in Maine. They probably have been elsewhere in New England. These fungi also are important at times near Charleston, S. C., and possibly elsewhere in the humid East, but Landis and others (personal communication) observed that fungi were of little or no importance as a biological agent for aphid control on potatoes in the Yakima, Wash. area. The fungi appear to affect aphid abundance on potatoes in two ways. At times in the Northeast, aphid populations on potatoes may be decimated in just a few days. In other years when epizootics do not develop, the fungi still appear to provide a substantial degree of aphid control, particularly of the potato aphid. In northeastern Maine, we have observed that the rate of population growth of this aphid on potatoes begins to decrease as soon as we find the first fungus-killed aphid in the potato field, and also that populations of this aphid have never become large if dead and diseased specimens appeared early in the summer. This suggests the possibility that sublethal infections of fungi may occur, which substantially reduce the biotic potential of aphids, or sampling methods may fail to reveal the true picture of infection.

At the Connecticut Agricultural Experiment Station, J. B. Kring found that wireworms are killed by a toxic metabolic by-product of the bacterium Pseudomonas fluorescens Migula when the insect cannot escape the environment containing the bacterium. (This bacterium is generally considered nonpathogenic to animals.) He showed that the wireworm control observed when rye was plowed under as a green manure crop in spring is the result of toxins given off by Pseudomonas in soil containing the decomposing plants (J. Inst. Pathology 4: 257-266, 1962).

Biological Control

In recent years, the Entomology Research Division, in cooperation with State Agricultural Experiment Stations, has initiated several projects on biological control of aphids in potatoes, in an alfalfa-English peas complex, in sugarbeets, and in tobacco. The biological agents or other methods of control being employed include parasites, predators, and bio-environmental control.

Overflooding with parasites to suppress populations of the pea aphid and spread of pea enation virus.--The experiment with overflooding of parasites has been in progress in Washington for about 4 years. Its purpose is to determine whether populations of pea aphid, Acyrthosiphon pisum (Harris), and spread of pea mosaic virus in 60,000 acres of peas can be suppressed by controlling the aphid on 18,000 acres of alfalfa with parasites early in the season before the insect migrates from the alfalfa to the pea fields. The biological investigations and greenhouse mass rearing of the pea aphid parasites are done at Yakima, Wash. The field releases of the parasites, Aphidius pulcher Baker and Praon pequodorum Vierick, are made from March to May each year, principally in the Gardena Bench area south of Walla Walla, Wash. The study is being conducted by J. E. Halfhill and P. E. Featherston under the direction of B. J. Landis.

Sustained releases of parasites to suppress populations of aphids on potatoes.--The Entomology Research Division in cooperation with the Maine Agricultural Experiment Station, began an experiment at Presque Isle, Maine, in 1966 to determine whether aphids in small plots or small fields of potatoes can be controlled by releasing known numbers of the parasites Aphidius matricariae Haliday and Praon sp. weekly for 6 weeks during the early part of the season while aphid populations are very small. We think the two species accidentally gained entrance at Presque Isle in 1964. Both are very effective against the green peach aphid, Myzus persicae (Sulzer)--far more so than the same or closely related species "native" to the area. Only limited progress has been made in this experiment because of difficulties encountered in mass-producing the parasites. The biological investigations of these parasites, development of techniques for mass-producing them, and evaluation of the field releases are being carried out jointly by the Entomology Research Division and the Maine Agricultural Experiment Station.

Field releases of predators on tobacco.--In 1965, the Entomology Research Division found that the release of larvae of Chrysopa sp. on tobacco infested by the green peach aphid in Florida or in Missouri did not control the insect. In the Missouri tests, the larvae left the plants and were found the next day on the cage walls. Observation indicated that first instar larvae of Chrysopa sp. placed on tobacco leaves could move only with difficulty--tobacco leaves have many hairs, each tipped with a droplet of stickly resin, and the small chrysopid larvae remained stuck to the top of these hairs, unable to reach the leaf with their legs. The aphids are able to move freely over the leaves.

Sustained releases of predators on potatoes.--At Presque Isle, Maine, we began tests in 1964 to determine whether 6 weekly introductions early in the season of Coccinella septempunctata L. and Chrysopa spp. would control aphids on potatoes in small plots. Field introductions of the eggs and the larvae of these predators were compared in 1964 and in 1965, but in 1966 only the larvae are being used.

In 1964 the results were promising. All-season control of the green peach aphid as high as 85 percent was obtained with chrysopids and as high as 78 percent with the coccinellids. However, average control of the green peach aphid was much better than that of the potato aphid--65 percent and 11 percent, respectively. Depending upon the "predator treatment," the all-season control of all species of aphids ranged up to 56 percent. The results in 1965 were not as clear-cut largely because of interplot movement of the introduced predators. This movement prevented us from fully measuring the impact of the predators on the trends of aphid population both in 1964 and in 1965. Chrysopids gave better control of the green peach aphid than of the potato aphid; coccinellids tended to use the potato aphid as food more often than the green peach aphid. Perhaps when a complex of aphid species occurs on potatoes, more than one species of predator should be introduced when one species of aphid is preferred by one species of predators.

In 1966, we are making the introductions in small fields (1/4 acre) and in small plots. Also a concerted effort is being made to devise a barrier to interplot movement of the predators. If we are not successful, we will shift the emphasis to larger fields and to more intensive techniques of mass production of the predators.

Bio-environmental Control

"Bio-environmental control" is the term used to imply control of an insect by altering some part of its environment to the extent that not all of its survival requirements are satisfied during a critical part of its seasonal history. Three kinds of environment alteration are being tested to see whether they will give control of the green peach aphid on commercial crops over large areas. The approaches being tested for area control of this aphid are:

By control of overwintering herbaceous host plants.--During the past 2 years, a study has been in progress to determine whether killing the herbaceous plants serving as overwintering hosts of the green peach aphid in an area will provide control of the aphid and the virus diseases it spreads in sugarbeets within that area. The test is being made in a 22-square mile area 4 miles

southwest of Toppenish, Wash., where excess water collects in drainage ditches. There is enough winter protection for summer forms of the green peach aphid during most winters to survive on winter hardy plants growing in these ditches. Some of these plants also serve as reservoirs of two aphid-borne virus diseases of sugarbeets. Truck-mounted butane burners are being used to clean out the aphids and weeds in the ditches in a 22-square-mile area. The experiment is being conducted by R. L. Wallis and John Turner, U.S.D.A. Entomology Research Division, under the direction of B. J. Landis.

By insecticide treatments on the primary host.--For the first time in 1966, an effort is being made to determine whether summer populations of the green peach aphid on sugarbeets and on potatoes over a large area can be suppressed by applying an insecticide to its primary host in spring within that area. This 275 square mile area is in Grant County, Wash., between Vantage and Othello. In April, about 4,500 peach trees (all peach trees known within the area) estimated to contain more than 40 million overwintering green peach aphid eggs were sprayed with an aphicide before any migration of the aphid occurred. The control area is located to the west (windward) of the main potato-producing area of Washington where about 42,000 acres of potatoes and 35,000 acres of sugarbeets are grown. The control effort is being evaluated by the use of aphid traps and by determining the prevalence of current season spread of leaf roll. This experiment is being conducted by D. M. Powell and W. T. Mendor, also under the direction of B. J. Landis.

By eradicating the primary host.--In 1966, in cooperation with several agencies, including the Maine Agricultural Experiment Station, the Entomology Research Division began a pilot-plant study in Maine. The purpose was to determine whether populations of, and disease spread by, the green peach aphid in potatoes could be reduced by eliminating the Canada plum (Prunus nigra Aiton), the only recognized primary host of the aphid in that area. Two districts in northeastern Maine that are isolated from each other by 50 to 60 miles of forest are being used, one a control area of about 100 square miles bordered by Lee, Mattawaumkeag, and Lincoln, and the other a check area of about 20 square miles immediately S-SW of Houlton. The aphid situation existing in both districts before eradication of the primary host will be determined by aphid counts on Canada plum in the spring and fall, by aphid trap catches in the spring and summer, and by observing population trends of aphids and leaf roll spread in untreated potatoes. Herbicides will be applied during the midsummer to all thickets of Canada plum found in the control area. Although not all the treated plum may be killed in time to prevent fall breeding of the aphid in 1966, the plants will have no foliage in 1967. Similar

observations and data in 1967 will permit us to assess the results of the experiment. Also, in a third area of 2 square miles at Bridgewater, a study is being made to determine the feasibility of using aerial photography instead of ground survey to determine the distribution of the Canada plum. If aerial photography can be done accurately, the saving in time over that required for a ground survey will be worth consideration should the eradication program be extended to all the potato districts in northeastern Maine.

SUMMARY AND CONCLUSIONS

Many unsolved problems have prevented us from obtaining uniformly adequate control of the most important insect pests of potatoes with insecticides. While research is steadily going forward to improve safe control of potato pests with insecticides, we are at the same time experimenting with several concepts of biological and bio-environmental control of aphids. The biological agents now being investigated are insect parasites and predators. We hope soon to include entomogenous fungi. The bio-environmental controls include controlling the aphids before they reach potatoes or other crops by burning the overwintering herbaceous hosts during winter, spraying the primary host with an aphicide in spring, or eradicating the primary host with an herbicide. The early results suggest that both biological approaches are promising or are worthy of intensive investigation.

The various methods of biological control require thorough knowledge of the biology and ecology of the pest insect and the biological agents of control, and acquisition and use of such information may require considerable time. Until reasonably satisfactory biological controls can be developed, we must continue to rely on our conventional methods of chemical and cultural insect control on potatoes. As the biological methods evolve, they can doubtless be integrated to advantage into the conventional methods.

ENZYMES AND SUGAR CHANGES IN POTATOES DURING STORAGE

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The accumulation of reducing sugars in potato tubers stored at low temperatures, as well as their subsequent disappearance when the tubers are returned to higher temperatures, is well known. Recognition of the primary importance of reducing sugars in determining the suitability of potatoes for processing has led to considerable research on sugars in potatoes. Numerous reports have provided detailed information on changes in the sugar balance of tubers during storage. However, the biochemical pathway of sugar accumulation during cold storage remains essentially unknown.

The results of studies on the sugar balance in potatoes suggest a sucrose intermediate in reducing sugar formation. This in turn suggests the participation of the enzyme invertase in the pathway. The presence of invertase in potatoes has been known for some time but studies on this enzyme have been hindered by an endogenous inhibitor. We have now developed a procedure for selectively inactivating the inhibitor in extracts of potato tubers. Briefly, the method consists of blending potato extracts at pH 4.7 and 37°C. for 10 minutes in a Vir Tis homogenizer. The foaming destroys the inhibitor but not the enzyme. Analysis of extracts before and after blending therefore gives the basal and total invertase, respectively. This procedure for measuring invertase was applied to tubers stored under various conditions during the past season to ascertain the relation of invertase to sugar accumulation.

Tubers placed into 18°C. immediately after harvest accumulated only low levels of both total and reducing sugars. A significant level of total invertase developed at this temperature but basal activity did not appear. Tubers at this temperature remained in good condition for about 10 weeks.

The changes in tubers stored at 4°C. were much more pronounced. Total and reducing sugars increased rapidly immediately after the tubers were placed in cold storage. After 3 to 4 weeks the rate of sugar accumulation decreased and the levels remained essentially constant on continued cold storage. Accompanying the formation of high levels of sugars was a rapid increase in total invertase and the development of basal invertase activity. Invertase continued to increase for 3 to 4 weeks and then decreased quite sharply. After 6 to 10 weeks of cold storage, an excess of the inhibitor developed in the tubers.

Reconditioning of cold-stored tubers at 18°C. resulted in sharp decreases in sugars and total invertase. Basal invertase, if present in the tubers, disappeared rapidly and an excess of inhibitor always developed. The level of inhibitor was dependent on the duration of cold storage prior to reconditioning, with maximum levels occurring in samples cold stored 12 to 16 weeks. Most of the changes during reconditioning occurred during the first 2 weeks at the warmer temperature.

In one experiment potatoes were subjected to alternating temperatures. The tubers were stored at 4°C. for 6 weeks, reconditioned 6 weeks, transferred back to 4°C. for 8 weeks and reconditioned again. The changes in sugars and invertase occurred reversibly as the temperature was alternated. Each time the tubers were placed at 4°C., sugars and invertase increased. During each reconditioning period sugars and invertase decreased sharply. An excess of the inhibitor developed during reconditioning and disappeared during cold storage.

From the nature of the variations of invertase and their relation to changes in reducing sugars, it is concluded that invertase is the final enzyme in the metabolic scheme of hexose accumulation in potato tubers. Moreover, the invertase system consisting of the enzyme and its inhibitor appears to regulate sugar accumulation.

SHRINKAGE OF POTATOES IN STORAGE AND ITS CAUSES

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From the potato grower's point of view, the main requirement of a method of storage is that it allows him to remove a quantity of salable potatoes as nearly as possible equal to the weight initially stored. On the other hand, the primary concern of the consumer is that the quality of the potatoes after storage should be optimal for his or her requirements. So, to a certain extent the concern of the grower and consumer is the same, because the shrinkage and disease which mean loss of weight to one, mean reduction in quality to the other.

Shrinkage, or the loss of weight and volume, in stored potatoes may be regarded as falling into two main classes or categories: (a) natural--the loss of solids from respiration and the loss of water from transpiration and sprouting; and (b) pathological--from bacterial and fungus disease and physiological breakdown (28). Shrinkage in the natural category is rather constant but will generally increase as air circulation rates are increased. The loss may range around 5 to 7 percent without forced air circulation to 10 percent or more with forced air. Most of this shrinkage is due to water loss (transpiration) (5).

Losses in the pathological category will vary from year to year, depending upon the incidence of rot organisms and various other factors. As pointed out by Wilson and Boyd (27), losses from pathological causes can generally be controlled or reduced by applying known methods, whereas natural losses cannot be controlled.

Respiration.--The rate at which a potato normally respires during storage depends partly upon the existing temperature with the respiration rate increasing with increase in temperature. Hopkins (14) has shown that the minimum rate of respiration of potato tubers occurs at a temperature of 37.4°F.

Broadly speaking, the main changes in the tuber during the storage (dormant) period are a reversible conversion of starch to sugar, and the oxidation of sugars, with the production of carbon dioxide during respiration. Dry matter is thus lost during storage at a rate depending upon the rate of transpiration, and in addition the starch sugar ratio may change according to the equilibrium reached between the hydrolysis of starch on the one hand, and the condensation and oxidation of sugars on the other (6).

In commercial storage at temperatures of 41° to 50°F., a steady production of about 2 to 4 mg. CO_2/kg./hour is probable (21). Taking starch as the primary material respired, this rate of respiration would involve the loss of 1.2 to 2.5 mg. of dry matter/kg./hour, which is equivalent to about 1 percent of the dry matter of the tuber in 5 to 10 weeks (6).

The rate of respiration can be accelerated or decelerated by various factors. Salunkhe and others (18) reported that tubers from maleic-hydazide-treated vines had a greatly reduced rate of respiration during storage and conditioning. However, Sawyer and coworkers (19) reported more shrinkage in potatoes treated with MH than from TCNB or MENA-treated potatoes. It has been shown that individual tubers of the same variety exhibit considerable variation in respiratory activity (22). However, this may be mostly due to a difference in maturity of the individual tubers. Immature potatoes have been found to respire much more rapidly immediately after digging than did mature ones (20).

Transpiration (Evaporation).--Loss in weight due to respiration is very small in comparison to the loss in weight caused by evaporation of water. Smith (21) reported that in common storage during a 7-month period shrinkage from respiration was only 0.51 percent, whereas from transpiration the shrinkage was 5.71 percent. Knudsen (17) stated that the loss of dry matter, nearly all as carbon, by respiration, amounted to about 0.07 percent of the stored weight per month. This was much less than loss by the evaporation of water.

The rate of water loss by transpiration is nothing more than physical evaporation and is determined by the water-vapor-pressure deficit of the environment. Other factors involved are the rate of air movement over the tubers and the resistance to water loss provided by the skin of the tuber. The rate of water loss is increased by a decrease in the relative humidity, by an increase in the air velocity passing over tubers, and by immaturity and an inadequate curing. Because of the presence of a corky skin the rate is very low--about 2 mg./week/cm.^{2} surface/mm.Hg.VPD from mature potatoes which have been stored for 1 month (3). The rate is higher immediately after harvest probably because of skinning, and increases again at the end of storage because of sprouting.

Sparks (23) reported that in Idaho potatoes stored in bins had slightly more shrinkage at higher airflow rates (up to 40 c.f.m./ton). Sawyer (19) reported less shrinkage in ventilated storage (0.83 c.f.m./cwt.) when moisture was added, but Colorado State University agricultural engineers found no significant difference in shrinkage between potatoes stored under humidified vs. non-humidified conditions (1). In Maine we have found that in

high-temperature storage the high airflow rates, in the order of 1.8 c.f.m./cwt., result in severe pressure bruising and internal blackspot from excessive loss of moisture. Severe losses have been reported in New York State from improper use of forced air ventilation (13). Johnston and coworkers (16) reported slightly more shrinkage in pallet-box storage than in bulk-bin storage held at the same temperature without forced air circulation. The greater amount of weight loss in potatoes stored in pallet boxes indicates that moisture moved more freely from the potatoes to the air of lower relative humidity than when potatoes were stored in a larger mass. Studies at the Maine Research Center the past storage season showed a greater weight loss in high-temperature bin storage with intermittent forced air through ventilation than in pallet boxes. Claycomb (8) reported that sound potatoes harvested and handled with reasonable care and cooled slowly by gravity circulation within the pallet boxes can be expected to evaporate slightly less than 5 percent of their weight during 6 months' storage in a well-regulated, insulated storage.

Claycomb (8) also reported that in a well-constructed and regulated storage with pallet boxes, gravity air circulation, and less than 5 percent weight loss in 6 months, shrink will be as much as 7 to 9 percent during the same period as with continuous forced-air circulation through the boxes. Butler (7) measured total loss of weight of the Green Mountain variety stored at 50°F. from the end of January. He found that tubers over which air was allowed to flow freely lost 8.96 percent of their initial weight after 90 days and 17.24 percent after 119 days. In still air the losses were 1.35 percent and 2.79 percent, respectively. He also reported increased loss with an increase in storage temperature. This effect was probably mainly due to the lower relative humidity that accompanied the higher temperatures and to increased respiration.

Edgar (9) stressed the importance of curing by keeping tubers at about 60°F. and approximately 90-percent relative humidity for 2 weeks after digging and before storage at low temperature. Appleman and others (3) reported that at low temperatures (35° to 41°F.) freshly dug potatoes lost water more rapidly than at higher temperatures. Appleman and Miller (2) found weight losses varying from 16.45 percent in immature tubers to 4.62 percent in mature tubers. The loss was almost completely water. In Maine, fall washed potatoes shrank slightly more than nonwashed (6.81 to 5.03 percent).

Although we generally think of shrinkage as a weight loss, volume loss can be important too. Studies in Maine have shown that a loss of volume could result in potatoes being out-of-grade.

In these studies as many as 50 percent of the tubers in a size range fell into the next lowest size group.

Sprouting.--The timing of the natural sprouting of any given variety of potatoes is influenced greatly by the storage atmosphere. The temperature of the tuber at the end of its rest period and during subsequent storage has a great influence upon the time the tuber will continue to remain dormant (24). Tubers that are mature at the time of harvest sprout sooner than immature ones (22).

When dormancy is broken at the end of the storage season, the rate of water loss from the tuber is increased. This increased rate of water loss is the result of the sprout surface being 30 to 40 times as permeable to water as is the mature tuber skin (4). It has been demonstrated that considerable sprouting is accompanied by loss of starch and of total pectins and a decrease of ascorbic acid. These losses were generally avoided by using CIPC and IPC (26).

The recent changes in the storage of potatoes for processing have magnified the problem of controlling sprouting and increased the problem of internal sprouts. Much of the internal sprout increase is due to higher storage temperatures. However, some of the problem is caused by faulty applications of sprout inhibitors and to a combination of both.

Findlen (10) reported that sprouting and subsequent weight loss and shriveling of unskinned Irish Cobbler and Kennebec potatoes stored in 1-ton pallet boxes at an average temperature of 56°F. and 60 percent relative humidity (RH) were successfully controlled by foliar application of maleic hydrazide (MH). In Maine we have obtained good results with properly timed application of MH.

Diseases.--Losses in this category will vary from year to year depending upon the incidence of diseases and the storage atmosphere during the curing and holding period. Twiss and Jones (25) surveyed the wastage in Great Britain and reported that losses from rotting were 15 percent of the original weight. This was three times greater than the combined losses from respiration and transpiration.

The increase in mechanical harvesters and in high-temperature storage is resulting in more disease problems in storage, particularly with improper curing of the crop. We sometimes forget that low-temperature storage not only suppresses sprouting but also suppresses disease development in storage. Although the pathogens are able to grow in low-temperature storage, they grow very slowly,

thereby the rate of disease spread is reduced. Because of slow development of the disease, it is generally possible to escape heavy losses. However, as storage temperatures increase, they approach the optimum temperatures for growth of many of the storage disease pathogens, which means that the disease development rate will be accelerated to the point that an endemic disease will become an epiphytic one. Examples of this are Fusarium tuber rot fungi that may be practically inhibited at 32° to 40°F., but become increasingly active at temperatures of 46° to 50°F. Breakdown in storage from Verticillium wilt pinkeye infection is a problem in storage for chips, but is generally unimportant in low-temperature storage because the minimum temperature for the fungus is 41°F. The rate of growth of the late blight fungus (Phytophthora infestans) is increased as the temperature approaches 60°F. and with high humidity lesions are reported to spread as much as 2 inches in 10 days. The optimum temperature for this fungus is 54° to 55°F. The optimum temperature for soft rot bacteria is in the range 60° to 85°F. and breakdown will occur from 46° to 92° with acceleration as the temperature increases. This disease generally acts as a secondary following other disease, such as late blight tuber rot, ring-rot, and field frost; but, under some conditions of high moisture, the organism will invade the lenticels. Ring-rot develops slowly at 37°F., but as the temperature approaches 60°, the rate of development increases rapidly.

Field frost or low-temperature injury causes severe losses in some years. The 1965 losses from field frost in Maine have been estimated at 20 percent and in some storage losses were as high as 50 percent. Losses in the Red River area were reported to average higher than those in Maine. The losses in Maine were reduced where through ventilation at high rates could be applied. At the Research Center, we found that by using a high air circulation rate (3 c.f.m./cwt.) field frost could be dried up to the extent that potatoes could be marketed without washing. Data collected from salvage tests revealed that 43.8 percent of the potatoes which were rehandled (field frost removed) and washed before restoring were in the moderate to severe category of the lenticel infection index, whereas, 78.5 percent of those similarly handled without washing were in the same categories. There was no significant difference in soft rot breakdown in this test. Some desiccation occurs at these high airflow rates, but, as Burton (5) stated "it is better to have wilted potatoes than to lose them by rotting."

As stated by Wilson and Boyd (27), shrinkage from pathological breakdown can be controlled by known methods. Hunter and Toko (15) reported that the development of soft rot in low-temperature storage and the subsequent weight loss were reduced as through-ventilation airflow rates were increased from 0 to

2.4 c.f.m./cwt. However, at the 2.4 c.f.m./cwt. rate there was a relatively high weight loss. It was reported from Long Island (11) that dry rot in bruised tubers inoculated with Fusarium sp., stored in bins held at 50°F., and with relative humidity of 80 to 85 percent was reduced by forced-air shell ventilation. The incidence of dry rot was higher in bins maintained at a similar temperature and relative humidity with forced air through ventilation. Current studies in high-temperature storage at the Maine Research Center has shown that soft rot and Fusarium tuber rot can be controlled by forced-air through ventilation at 1.2 and 1.8 c.f.m./cwt. However, as noted by Hunter and Toko (15) in low-temperature storage, there is severe desiccation of tubers unless moisture is properly added to the atmosphere. The desiccation leads to severe pressure bruising and internal black spot development.

Conclusions.--Loss of weight and volume in stored potatoes results from loss of solids from respiration, loss of water from transpiration and sprouting, and breakdown of tissues from bacterial and fungus diseases and physiological disorders. Losses from natural functions are rather constant and are not generally controlled, whereas, pathological losses vary from season to season and can generally be controlled.

Probably the best "tool" we have for controlling or reducing pathological losses is the proper use of forced ventilation. Ventilation affects the quality of potatoes in storage primarily because of its relation to temperature and humidity of the storage atmosphere. Ventilation may imply the introduction of outside air or merely the recirculation of air within the storage. The introduction of outside air generally is a rapid means of changing the temperature and the relative humidity in the storage. Ventilation usually tends to lower the relative humidity surrounding the potatoes unless the incoming air is near saturation. Reduction of humidity is a means of preventing disease spread, but it also increases water loss. Storage operators should be aware of the influence of ventilation on the humidity surrounding the tubers as well as in providing a more uniformly desirable temperature. In general, the least shrinkage and best quality potatoes result if the relative humidity is maintained near 85 to 90 percent. Recent reports have emphasized the importance of observing two principles when adding moisture to a storage: (a) All water droplets should be completely atomized in the storage atmosphere and (b) the moisture should be added to the air before it comes into contact with the tubers (11).

Because of the importance of moisture in the storage environment and because of the effect of forced air on shrinkage, it has been suggested by Burton (5), Wilson and coworkers (29), Hunter and Toko (14), and others that ventilation be restricted once the holding temperature has been reached and rots are under control.

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MODERN POTATO STORAGE

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In discussing modern potato storages, three factors continually come to our attention. The first two (temperature and humidity) are fundamental principles, each of which is controlled and regulated by the third factor. The third is ventilation or airflow. These factors are far more important than type of external or internal structure of the building. By proper management of temperature and humidity through ventilation and addition of sprout inhibitors, it is possible to maintain potatoes sprout-free and in very high state of quality for periods of 10 to 12 months, or longer if necessary.

Temperature and humidity are very closely interrelated, especially immediately after harvest. During this period, potatoes are forming wound periderm and healing from the bruising caused during the harvesting operation. Recent research at the University of Idaho Aberdeen Branch Experiment Station shows that a temperature of 45° to 50°F., combined with a humidity of 95 percent or more, resulted in the best wound periderm formation. Potatoes stored at 45°F. formed a greater number of layers of periderm cells than potatoes kept at either 38°, 52°, or 59°F. Also, the amount of rot and weight loss of potatoes stored at 45° was less than that found at the other temperatures (tables 1 and 2).

Table 1.--Effect of storage temperature on rot and weight losses of cut Russet Burbank seed potatoes

Temperature	Rot	Weight	Total
°F.	Oct.	Oct.	Oct.
38	5.7	5.7	11.4
45	5.8	5.0	10.8
52	6.5	5.9	12.4
59	11.3	7.2	18.5

Table 2.--Effect of storage temperature on rot and weight loss of bulk Russet Burbank potatoes (10 months' storage, 1965)

Temperature	Rot	Weight	Total
°F.	Oct.	Oct.	Oct.
40	2.70	9.46	12.16
45	0.59	8.97	9.56

During a prolonged storage period, temperature control is an absolute necessity. Potatoes stored at 45°F. have been found to have a lower weight loss than potatoes stored at 38° or 52°F. Also the quality of potatoes stored at 45°F. is higher than that of potatoes stored at 38°F. and equal to the quality of potatoes stored at 52°F.

Work now under way shows that potatoes stored at 45°F. have significantly lighter french-fry color than those stored at 42°F., and about the same french-fry-color as tubers stored at 48°F. There is very little difference between the buildup of sugars in tubers stored at 45° or 48°F., but both are significantly lower in sugars than tubers of the same lot stored at 42°F.

HARVESTING POTATOES INTO WATER

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Although exact biochemical and/or physical explanation of the causes of susceptibility and resistance to internal blackspot, and to its development, have not been clarified experimentally, it is a fact that initiation of the discoloration reaction requires an impact. Unbruised tissue does not turn black. Although basic studies of the factor, or factors, associated with susceptibility and resistance to discoloration could possibly lead to a positive and dependable control of the disorder, the most economical and practical control method now in use is to prevent impacts from occurring. Reducing the speed of conveyors prevents excessive bouncing and rolling of potato tubers and has helped to reduce injury. Rubber or plastic coating of the equipment with which the tuber comes into contact has also helped to prevent bruising injury. Impacts have been reduced by unloading potato tubers from trucks into water, and by fluming potatoes from storage cellars. More recently, water has been used to wash tubers out of truck beds and into even-flow bins, also filled with water. Since water is one of the best cushioning agents known, and since it is readily available in any field in an irrigated area, it was decided to extend its usefulness to the field operations.

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In studies made at Washington State University during 1960, it was found that almost 75 percent of the overall injury from digging through shipping occurred during operations in the field. One important source of injury was excessively long drops from the loading boom to the sides or bottom of steel or wooden truck beds, or drops on other tubers. Careful operation of the truck, or harvest machine, helps keep the falling distance to a minimum and reduces the severity of injury. However, even with the most careful operators, unavoidable obstacles and faults in the ground still result in considerable injury. Therefore, to be totally effective, the method devised to eliminate blackspot injury must reduce all impacts regardless of the way in which tubers are handled.

Figure 1.--Specially designed truck for harvesting potatoes into water.

A steel V-shaped truck bed capable of holding 5 to 6 tons of potatoes was mounted on a surplus army truck (fig. 1). A water pump, used to draw water from the irrigation canal to fill the truck bed, was mounted behind the cab. In actual practice, it would be best to mount a pump on a pickup truck so that it could be readily moved within the field and from field to field. In operation, the truck was filled to approximately 30 inches in depth (about 2,000 pounds) with water from the irrigation canal nearest the field being harvested. The truck was then driven under the harvester and the loading boom was inserted into the water. In this way, tubers, stones, and clods were led into water during the initial period of loading, at the time when the most severe impacts occur. It was estimated that two-thirds of the load was afforded the cushioning protection of the water, thus eliminating the close control of the truck and harvest machine operations. Potatoes could be placed into the truck bed at any location because the load could be easily leveled by briefly letting up on the gas and then quickly accelerating. In addition to eliminating impacts, vines that had not been eliminated by the harvester

floated to the surface and could quickly be removed. When tubers were no longer afforded the protection of water, a gate at the back end of the truck was opened and the water was slowly drained as the load was topped-off dry. During the drainage period the truck must not be stopped too long in any one spot without closing the gate, or it could become mired in mud.

At the receiving warehouse a 2-1/2 inch hose attached to the sump pump was connected to the lower front end of the truck and some of the flume water was diverted through the bed to wash out the tubers.

The usefulness of this technique becomes apparent in many ways. First, and most important, a substantial reduction in blackspot injury was realized. Essentially no blackspot blemishes, in addition to those already produced by the harvester, were observed on tubers harvested into water. On the other hand, the number of blackspot blemishes on tubers harvested into conventional beds was doubled. Intensity of color of blemishes was also much more severe on tubers harvested into conventional truck beds. Although considerable external injury such as splits, cracks, and cuts, developed upon contact with the bed while harvesting into conventional truck beds, external injury was essentially eliminated by dropping potatoes into water.

Harvesting into water also reduced the amount of high temperature injury. Direct rays of sunlight during warm still days increased steel-bed temperatures to 150°F. or higher. Tubers coming into contact with metal at this temperature can sustain severe burns that do not heal and, thereby, offer excellent ports of entry for rot organisms. Cooling the bed with water prevented contact burns from occurring. Also, if a breakdown did occur in either the harvest machinery or truck at a time when the bed was only partly loaded, the water would temporarily prevent excessive buildup of tuber temperature. There was a definite cooling effect of the water on tubers harvested at temperatures higher than that of the irrigation water. Wet tubers also reduce the amount of windburn incurred by tubers during movement from the field to the receiving shed. Excess water on the tuber is dried before tissue water is removed. This enables tubers to be hauled over longer distances without damage and prevents some drying out from torn or poorly tied tarpaulins.

Draining the loading water in the field also results in the removal of considerable quantities (200 to 300 pounds in several 5-ton loads of tubers) of dirt that had been loaded into the truck. Dirt carried into the weighing station costs money, and it can also plug sumps in fluming systems, causing expensive cleaning delays.

Ability to wash tubers out of the truck eliminates the need for built-in conveyors or for hoists at the receiving shed. This would make the truck bed cheaper initially and more economical to maintain. Besides being costly to maintain, moving parts, such as built-in conveyors, often result in more bruises and cuts, especially if pick-out boards are of uneven thickness, or are badly chipped and cracked.

It is obvious that harvesting into water will not solve the internal blackspot problem, but it is an effective way of eliminating bruising injury at one step in the handling operations. Similar methods of reducing bruising injury must be devised for the other steps in the harvesting, grading, packaging, and shipping procedures. Each method devised must be rigidly utilized if successful control is to be attained. Failure at any step along the way may completely overcome careful operations at another step and ultimately reduce the effectiveness of the overall operation.

PCNB SOIL TREATMENT FOR RHIZOCTONIA CONTROL AND ITS RELATION TO OFF-FLAVORS IN POTATO TUBERS

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Pentachloronitrobenzene (PCNB) has been shown to be highly effective for control of Rhizoctonia solani on potatoes, reduction of severity of stem cankers, and significant increase in yield. The proper use of PCNB has promise of becoming a very important means of Rhizoctonia control provided the flavor problem reported to occur as a result of PCNB treatment can be solved. There have been several reports of flavor changes associated with potatoes grown in PCNB-treated soil. Complaints of off-flavors have been received on marketed potatoes coming from soils where PCNB application rates were as high as 225 to 275 lb. per acre. Although flavor changes have been reported for treatment as low as 20 lb. per acre, heavier treatments are usually considered necessary for formation of objectionable flavors.

In order to get a better understanding as to the nature of the off-flavors produced, the changes in PCNB, or in any impurities present in this fungicide, were followed in the soil during the growing period. These experiments were conducted under controlled environmental conditions in the greenhouse. Specially designed water-bath soil temperature control units were used which allowed close experimental approximation of the temperatures normally

occurring in potato fields in Colorado. Soil moisture was also strictly controlled. Analysis was made on hexane extracts of potatoes or of soil with a gas chromatograph equipped with an electron capture detector.

A significant result of this analytical programming was that the gas chromatographic patterns of extracts of the potatoes and the soil they were grown in were almost identical. The only real difference was that the ratio of impurities and metabolites to PCNB were higher in the potatoes than in the soil. Evidently the potato more readily absorbs impurities and metabolites than PCNB. This is illustrated in figure 1. Substances represented by peaks 1, 2, 3, 4, and 6 were present as impurities in technical PCNB (Terraclor). Peak 1 is pentachlorobenzene and peak 4 is hexachlorobenzene (HCB) an impurity commonly found in Terraclor. Substances represented by peaks 1 and 6 appear to be formed in the soil as metabolites of PCNB. Peak 7 is definitely a metabolite since it is not found as an impurity in the technical PCNB and is evidently formed in the soil.

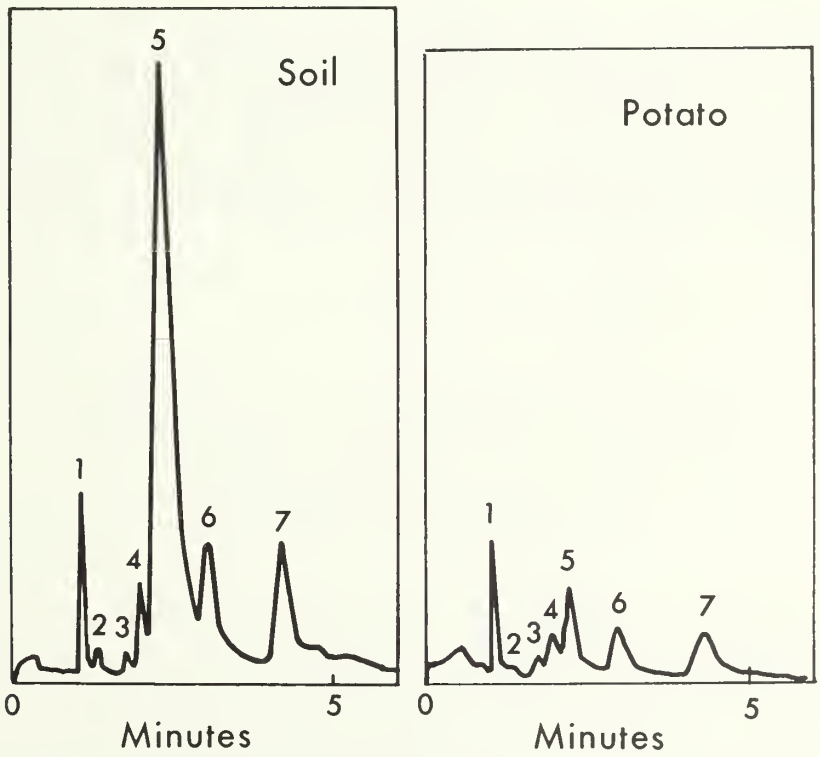

Figure 1.--Gas chromatographic patterns of extracts of soil and potatoes.

The rates of disappearance of PCNB (25 lb. per acre) in autoclaved and nonautoclaved soil were also determined. The

results indicated that in the absence of potato plants the disappearance of PCNB was somewhat faster in the nonautoclaved than in the autoclaved soil. This indicates that decomposition of PCNB by microorganisms may be an important factor in its disappearance. The half life of PCNB appeared to be approximately 3 to 4 weeks.

The taste panel for this study used the triangle test, two controls against one treated sample. For the lower treatments, the tests were inconclusive but for higher treatments there were definite indications of some flavor change. In one experiment Terraclor and HCB were applied each on separate plots at a rate of 250 lb. per acre; HCB is always present as an impurity in Terraclor. Taste panels found a noticeable off-flavor in both treatments. Recently it has been suggested that PCNB off-flavors "may be due to the accumulation of compounds produced by an altered metabolism" (of the potato). If this were the case, then this altered metabolism would not necessarily be produced by PCNB taken up by the potato since other compounds, impurities, and metabolites are taken up more readily than PCNB.

Surprisingly, taste panels found no off-flavor on samples of potatoes to which small amounts of PCNB, known impurities, and PCNB metabolites had been added. This indicated the off-flavor produced is not due directly to the flavor of PCNB or its impurities or PCNB metabolites present in the tuber. Other possibilities must obviously be explored. The flavor problem appears to be quite complex and requires much more work before it can be satisfactorily solved.

EXTRUDED FRENCH-FRY POTATOES FROM DRY MIX

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I very much appreciate this opportunity to discuss the future of instant french-fry mix. This will not be a scientific exposition--at least not in the concept of the physical scientist. My major experience has been in marketing. Such success as I have had has stemmed from application of that experience in the rather limited field of franchised fast-food-service operations at the retail level. Through association I am familiar with the entire institutional food market and I have devoted a study to the consumer in that market.

Let me say that my first exposure to, and immediate interest in, an instant french-fry mix did not stem from any altruistic desire to advance the cause of potato growers. To be quite candid, I was inspired by the profit motive. I first heard of a presumably marketable Dutch french-fry mix in 1963 and first saw it in 1964. At the time, I had no idea that American and other foreign scientists had been working to develop this type of product for many years, nor that at least one American company had unsuccessfully attempted to market a similar product. I did have a fair idea of the magnitude of the french-fry market in the United States and a good idea of the problems most restaurateurs had, and still have, handling and serving a consistently high-quality french-fried potato. I also had a very thorough knowledge of the goals of the A & W Root Beer Co., along with an understanding of the needs of that company's franchisees, subsidiaries, and associates. I regretfully discarded the idea of attempting to tie up the exclusive rights for my own personal gain because the only approaches available to me were impractical, financially unsound, and just a wee bit unethical. So, with help from business associates on both sides of the Atlantic, an exclusive distribution contract for A & W Root Beer Co. covering the United States, Canada, and Mexico, was eventually negotiated with the Dutch manufacturers. Despite the unexpected, numerous, and complex problems which have ensued, we're glad we did.

We and our associates fully expect to move 3,500 tons of instant french-fry mix into U.S. distribution channels during calendar 1967. This will amount to over 7,000 tons of french-fried potatoes as served, the equivalent of 9,300 tons of frozen pre-blanched french fries as sold, or the equivalent of about 18,600 tons of raw potatoes. Although not definite, it is likely that the mix distributed by our associates will be of U.S. manufacture using U.S. potatoes. We fully expect there will be one to three U.S. companies competing with similar products of U.S. origin, and we can only guess what they might sell in the way of volume.

Most of you are probably more familiar than I with the marketing problems encountered in the early years of the frozen french-fried potatoes and of the instant-mashed potato products. I feel that instant french-fry mix will command at least the same percentage of the total institutional-french fry market as the frozen product within 10 years. I further predict that aggressive marketing of the mix will add another 10 to 15 percent to the per capita consumption of potatoes in this country over that projected for 10 years hence. Why? Because this product makes it possible and practical for many food service outlets to serve a french fry where labor cost makes the use of raws prohibitive or where the limitations of proper distribution and storage facilities make the frozen product unavailable or impractical.

As the name implies, french-fry mix is a blend of dry powdered products. Selected grades of instant mashed product comprise approximately 90 percent of the mix. The rest is other pure food ingredients. The dry mix is stirred into approximately twice its weight of water to make a dough. The dough is extruded by machine into french-fry shapes, which are deep fried in a minute. Now for the advantages: A good marketing man considers the consumer first. If you have sat in as many drive-ins and hamburger stands as I have, you must have observed what young people are doing to your baby these days. When they are through loading on the ketchup, vinegar, salt, pepper and anything else at hand, don't you wonder if the potatoes are still identifiable as such? I do. But being a stubborn Kraut by descent, I persist in the belief that, consistently, high quality is the key to long-term success in any endeavor, and any restaurateur worthy of the name has the same belief. All of us here have tasted excellent french fries prepared directly from raw potatoes and an equally good product prepared from the frozen french fry. The customers of 300 A & W drive-ins and an even larger number of non-A & W restaurants have proved our belief that french fries prepared from our Super Fry mix are at least equally acceptable. However, the flexibility and ingenuity that may be exercised in formulation plus the controls that may be exercised in the processing and production, add up to the following benefits to the consumer (whether he truly appreciates them or not):

1. Unique flavor.
2. Consistent flavor, shape, texture, color, moisture, and fat absorption.
3. Faster service of fresh fried product.
4. Longer retention of flavor, shape, texture after frying.
5. Relatively stable low cost.

What do I mean by unique flavor? Fifty-two weeks per year of consistent quality are possible with a dry mix product. It is also possible to make that flavor just a little different, perhaps just a little more pronounced, so that it comes through the ketchup and the other goop. Or, it's possible to captivate those "who think young" and "way out" with other flavors such as onion, garlic, pizza, cheese, or you name it! And that flavor, unique or natural, can be consistent--the same every time! Most of the other advantages listed need no explanation--but, just a word about color. Would you find green, red, or purple incredible? It's possible--just name it. And about shape? Round, hexagonal, pancake, ribbon, or star-shaped are all possible. And, are you aware that restaurant take-home sales are growing at a much faster rate than on-premise sales, and that french fries are not growing in the take-home segment of this market because of their short-lived quality? Longer-lived quality is possible with a dry-mix formulation.

The advantages enumerated for the consumer are likewise primary advantages for the restaurateur. Additional pluses include:

1. For an equal number of servings, the french-fry mix occupies 1/15 the space needed for raws or 1/9 the space needed for frozen product.
2. It does not require refrigeration--the shelf life is indefinite. One could easily afford to guarantee 1 year, properly packaged.
3. The packing allows for easy inventory and cost control.
4. The extrusion process allows for easy portion control.

All of these amount to big, black numbers at the bottom of the restaurant owner's profit and loss statement.

All of the advantages enumerated for the consumer and for the restaurant owner are primary advantages for the processor of french fries as well as for the brokers and distributors. Can you imagine the savings in freight, storage facilities, handling, and warehousing costs?

For the marketing people, your biggest problem lies in overcoming the natural resistance of the order-taker to taking on something new, and the reluctance of the customer to do the same. Yet, twice in the past 20 years you have proved your ability to overcome such obstacles. We welcome your competition in the marketplace. It would help all of us in the food industry.

Those concerned with production and those in research and development may have three primary problems--developing a sound formula, establishing quality controls, and developing or acquiring a suitable extruding machine.

The development of a top-performing formula for an extruded french-fry mix requires a thorough knowledge of pre-cooked, dehydrated potatoes. A knowledge of such functional ingredients as vegetable gums, emulsifiers, and browning agents is likewise necessary. Not only do such finished-product characteristics as flavor, color, and eating quality have to be considered, but also dough formation, extrusion performance, and fat uptake.

Proper selection of a cohesive binder, such as a vegetable gum, is probably the most important single factor. Factors which are affected by the type of gum include the following:

1. Mixing time or rate of mix rehydration.
2. Time of dough setting before extrusion.
3. Water measurement tolerance.
4. Aging characteristic of extrusion dough (prevention of drying out or spoilage).
5. Breaking of both uncooked and cooked pieces.

6. Sticking together of pieces before frying.
7. Amount of fat absorbed during frying.

A minor problem, but nonetheless a problem, concerns the variation in sugar content of the granules resulting from potato storage. To maintain uniformity of recipe, formula variations have to be made to yield a uniform color in the finished product. Time does not permit my dwelling on the subject of quality controls even if I were qualified to do so--which I am not. And, if I knew all the answers to problems in developing the ideal extrusion machine, my company would be a lot farther down the road in their marketing.

SUPERHEATED STEAM IN EXPLOSIVE-PUFFING OF POTATO PIECES

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A dehydration process, operable at moderate cost, applicable to relatively large pieces of potato, which can yield a product capable of rapid reconstitution, has long been needed. Such products cannot be made by conventional hot air drying.

The reasons why are well put in the book POTATO PROCESSING, in the chapter on Dehydrated Diced Potatoes, from which I quote: "Piece size has a tremendous effect on drying rate. This has been a limitation in expanding the use of dehydrated foods and especially in producing products for remanufacturing uses as in stews, salads, and other recipes that normally use a relatively large piece. An increase in thickness of piece size from 1/8 to 1/2 inch will reduce dehydrator capacity by about 90 percent." Even if large pieces could be made by conventional hot-air drying, they would be case hardened, would probably have wet centers, and would require an extremely long time for reconstitution.

As a means of solving this problem, we thought it might be possible to modify the structure of a piece of potato so that drying and reconstitution could be accomplished rapidly. Obviously, these structure changes would have to be such that the texture of the reconstituted product would be as similar as possible to that of the fresh product. We wondered whether explosive puffing might accomplish this.

The puffing of cereals has been done for half a century and many of you have no doubt seen on television, antique cannon with puffed cereals exploding from their muzzles while a white-uniformed foreman repeatedly shouts "fire"--all to the accompaniment of Tchaikovsky's 1812 Overture. This is effective advertising, but not quite what we had in mind for potatoes.

In the puffing of cereals the object is to alter the structure of the grain, to increase its volume sometimes as much as 15-fold and to obtain a product with little resemblance to the starting material. This is accomplished with grain of low moisture content and puffing pressures of 200 pounds or more per square inch. In contrast, if our idea was to be successful the dehydrated pieces on reconstitution would have to come back to the same size, shape, and if possible the same texture as freshly cooked pieces of corresponding size.

To try this we purchased a small cereal puffing gun. It was made of heavy cast iron, rough on the inside, and had a primitive closing mechanism. It was heated externally with a gas flame and when sufficient internal pressure had been built up by vaporizing part of the water from the product to be puffed, it was fired by hitting the latch with a hammer. Even with this crude beginning, we were able to show that some unique dehydrated products could be made. Among these were 3/8-inch dehydrated potato dice which were ready for eating after 5 minutes of simmering instead of the much longer time required for conventionally dried dice of the same size.

The basic principle is quite simple. It merely entails partly drying the pieces generally to about 25 percent moisture and charging them into a gun where they are brought quickly to a temperature that superheats the moisture in the piece above its atmospheric boiling point. This is possible because the heating is done under pressure. When the gun is fired, a small percentage of the moisture is instantly vaporized which creates a porous structure. This enables the final stages of drying to be carried out in a conventional way with hot air but at a greatly accelerated rate. Moreover, final moistures lower than those feasible with unpuffed pieces can be obtained easily. Most important of all, the dried pieces take up hot water very quickly and are ready for eating after 5 minutes of boiling.

Having discovered that such a product could be made, we then began to discover, through further research, the many problems involved in preparation. For example, it was shown that the degree of porosity obtained is a function of the moisture content of the piece and the pressure in the gun at the time of discharge. But pieces, even cut from the same potato, have different moisture

contents when raw, and different moisture contents when taken from the preliminary drying stage. When puffed in this condition, with a pressure optimum for the average moisture of 25 percent, some pieces, being drier, puff inadequately and remain tough on rehydration; others, being too wet, disintegrate. We have found that this moisture variation among and within pieces can be reduced adequately by tempering or equilibrating the partly dried pieces by holding them in closed containers 8 to 10 hours before puffing. Since during the tempering period some moisture transfers from the centers to the surfaces again, the dice tend to stick together in the gun. By tumbling them with a coating agent, however, agglomeration in the gun has been eliminated. A sodium silico aluminate powder, used in salt and other products, has been found effective. It is in the class of additives generally recognized as safe by FDA.

These are some of the problems encountered and solutions found which have resulted in a process we feel is now commercially feasible. The steps in the process are as follows:

After washing, peeling, and trimming in the conventional way, the potatoes are cut to the desired size and shape (dice, slices, or chunks). These are washed to remove free starch, screened to remove slivers, precooked in water about 20 minutes at 165°F., then cooled 10 minutes in water. These last two steps insolubilize the starch and firm the pieces. They are then blanched and sulfite-dipped. Calcium firming can be done at this point if the potatoes have a high solids content with a tendency to slough. Preliminary drying is done conventionally to about 25 percent moisture. In order to equilibrate moisture both within and among the pieces, they are held in tempering bins for at least 4 hours. Then they are coated with sodium silico aluminate powder at a level of 0.75 percent based on potato solids. Thereafter, they are fed to a battery of puffing guns from which they pass to a final drier where moisture is reduced to 5 to 6 percent.

No suitable gun was available for puffing dehydrated fruits and vegetables. We therefore designed our own. It was built by a Philadelphia firm and has proved highly satisfactory. It has a capacity of 20 charges, each one 20 pounds of partly dried dice, per hour. This is equivalent to 320 pounds per hour of final product at 6 percent moisture. The gun is a stainless steel rotating cylinder 10 inches in diameter and 30 inches long. It has a hinged lid that can be opened or closed by a compressed air mechanism. Under the gun are gas burners used to maintain the wall temperature of the gun cylinder sufficiently high to prevent condensation of injected steam. Superheated steam is introduced through the gun shaft through a rotary valve and the rate of flow is controlled by an orifice in the lid. Operations are controlled from a pushbutton control station.

Operation of the gun is as follows: Starting with a cold gun, the gun wall is brought to 350°F. by rotating the closed, empty gun over the burners. The wall temperature is measured by a sliding thermocouple on its surface. The gun is then opened, tilted 45 degrees upward from the horizontal, and charged. The lid is closed and locked. The gun is then tilted to the horizontal position, the burners are lighted, and superheated steam is introduced. The wall temperature is maintained at 350°F. and the steam temperature at the entrance to the chamber at about 390°. These conditions are maintained until the steam pressure reaches 65 p.s.i.g. and for 1/2 minute at that pressure--a total time of about 1-1/2 minutes. The gun is then tilted to firing position, the gates of the collection chute are closed, the burners turned off, and the gun is fired. Steam flow is then shut off to the gun and shunted through the bypass. There is a loud bang and a burst of steam on firing. The charge is blown into the collection chute from which it is removed for final drying.

The superheated steam entrance lines are at the back of the gun. Steam flows in the line from the superheaters and while the gun is being charged or discharged, flows through a bypass line. Continuous flow keeps the lines hot and prevents de-superheating or condensing of the steam. The bypass ends in a back-pressure valve which keeps pressure in the superheater system and lines. After the gun has been charged, superheated steam is introduced by opening a quick-opening valve. Steam flows into the gun through the hollow shaft fitted with a ceramic liner for insulation. Temperature of the steam is measured by a thermocouple extending through the shaft to the entrance of the gun chamber. Pressure in the gun is indicated on a gage having its pressure tap through the shaft.

Why explosion-puffed dehydrated pieces rehydrate so rapidly is apparent from cross-sections showing their porous structure. On rehydration, the explosion-puffed material swells and the pores disappear, yielding products with good appearance and mouth-feel as in the freshly cooked vegetable.

In a comparison between fresh potato dice, conventionally hot-air-dried dice, and explosion-puffed dice, all cooked 5 minutes. The explosion-puffed product had fully rehydrated and resembled the fresh, while the conventionally dried dice had not rehydrated and were still shriveled. Comparison of explosion-puffed and conventional slices shows that the puffed slices are no more bulky than the now familiar product on the market. Explosion-puffed slices permit making scalloped or au gratin potatoes in 15 minutes of baking instead of the usual 35 to 45 minutes. Large pieces, 1-1/2 x 1-1/2 x 3/4 inches have been made by explosion puffing. They also rehydrate in 5 minutes of simmering.

What do explosion-puffed dehydrated potatoes cost? With the great reduction in cycle time and greater output made possible by use of superheated steam instead of external heating, the cost of explosion puffing has been reduced. Our estimate shows that to make 3/8-inch potato dice by explosion-puffing costs about 3 cents per pound more than 3/8-inch potato dice by conventional hot-air drying. This estimate is based on the use of batch guns and confirms our conviction that they are entirely feasible commercially.

Even so, we have not overlooked the possibility of a continuous puffer. A pilot line including this device has been installed. We expect to begin research on this line as soon as extensive rebuilding of our pilot plant area has progressed to a point where we can operate.

USE OF MICROWAVES IN PRODUCING LARGE POTATO DICE

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Microwaves are one form of electromagnetic radiation characterized by their frequency or length. More familiar forms of electromagnetic radiation are radio waves, TV waves, infrared rays, light waves, X-rays and the like. These names are used to categorize the various frequency bands of the electromagnetic spectrum. The wavelength varies inversely with the frequency so that the product of wavelength and frequency is always equal to the speed of light. The radio broadcast band corresponds to wavelengths of about 1 kilometer, and light waves are about 1 micron in length. Microwaves are usually considered to be those that vary in length from about 0.1 to 100 centimeters. Frequency bands require different types of generating and application equipment, and the interaction between the radiation and the material upon which it impinges varies from one frequency band to another.

When a material is placed in a microwave field, alternating voltage gradients exist within the material. This causes the molecules making up the materials to be strained and rotated first in one direction and then in another. At microwave frequencies these molecules undergo such strains and rotations millions of times each second. The movement of molecules next to one another gives rise to internal friction and the generation of heat.

For food processing, microwaves have several distinct advantages. They have a relatively high penetrating ability and thus cause an internal heating effect. Water molecules are particularly susceptible to microwave radiation, and therefore water tends to heat more readily than other constituents. It is also possible to concentrate the microwave energy to effect a very rapid heating. The primary disadvantage in using microwaves for processing is the relatively high cost per unit of energy. The question we must ask is: How can microwaves be used to advantage without prohibitive cost?

Microwave finish drying of potato chips is now an established process. The advantage is the selective absorption of microwave energy by water, so that the chips are dried rapidly and effectively without attaining excessive temperatures. This application has been extensively researched by the industry, and we have therefore decided to concentrate our efforts in other areas. One area which we felt needed improvement is the manufacture of dried potato dice, especially those of large dimensions.

Conventional processing of large potato dice has two main drawbacks. First, drying times increase markedly when the dimensions of dice are increased. Kueneman[1] states that increasing the dice size from 1/8 to 1/2 inch decreases dryer capacity up to 90 percent. Second, the rehydration of larger pieces is difficult.

Microwaves could be used conceivably to improve both drying and rehydration of the large potato pieces. The penetrating effect of microwaves and their high absorption by water can greatly reduce final drying time. This advantage alone, however, would not seem to justify the use of such a noble form of energy. Because microwaves can rapidly develop heat within the potato pieces it is possible to increase the vapor pressure within the drying product to such an extent that the piece will not shrink and will even expand in the final drying process. This results in a porous structure in the dried product and subsequently in improved rehydration.

The equipment required for microwave processing consists of a generator of microwave energy, a means of conveying the energy from the generator to the processing unit, and the processing unit. The generator is an electronic tube called a magnetron or klystron. Microwave energy is carried from the generating source to the processing chamber by a waveguide--a hollow metal tube of appropriate cross section. There are numerous possible types of microwave processing chambers; however, for continuous processing the recently developed conveyorized tunnels are most appropriate.

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[1]Ray W. Kueneman. "Dehydrated Diced Potatoes," in Potato Processing, eds. W. F. Talburt and O. Smith, Avi Publishing Co., Westport, Conn., 1959.

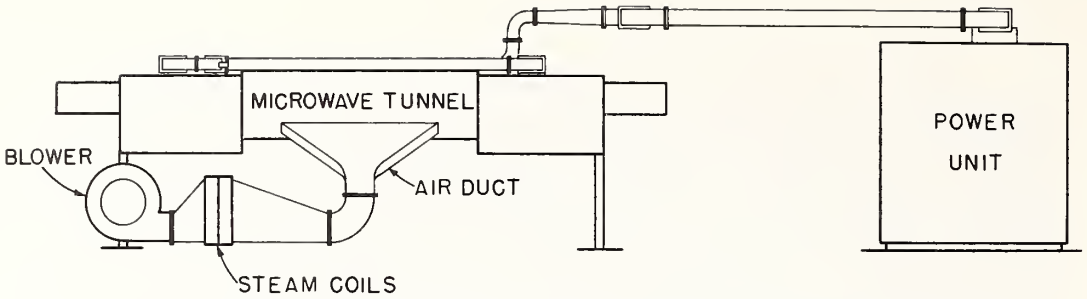

Figure 1.--Diagram of the microwave processing installation (Cryodry Model III-25NE).

Figure 1 is a schematic diagram of our microwave installation. The power unit generates up to 25 kw. of microwave energy at 915 megacycles. A rectangular waveguide measuring about 10 by 5 inches carries the microwaves from the magnetron to the conveyorized tunnel. Figure 2 is a cross section of the processing tunnel showing the perforated Teflon-coated fiberglass belt and the direction of heated air through the chamber. This system makes possible pilot studies of combined microwave and through-flow air drying.

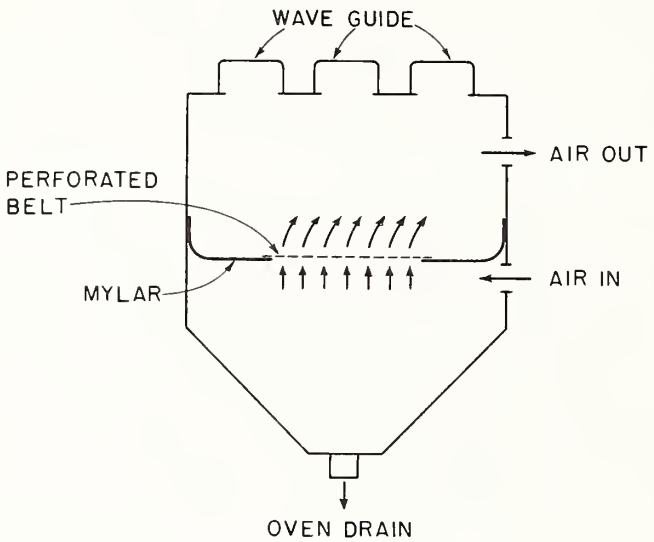

Figure 2.--Cross-sectional view of the microwave processing tunnel.

In order to broaden the scope of the microwave processing studies, an addition was made to the system as shown in figure 3. A 4-inch vacuum line was connected from one of the pilot-plant vacuum systems to the microwave tunnel as shown. A cylindrical chamber 30 inches long and 12 inches in diameter, made of filament-wound epoxy, was installed in the microwave tunnel. A reel-type plastic tumbler contains the product within the processing chamber. All materials used within the microwave tunnel are highly transparent to microwave energy. This means that material may be introduced into the chamber and treated with microwave energy in combination with reduced pressures.

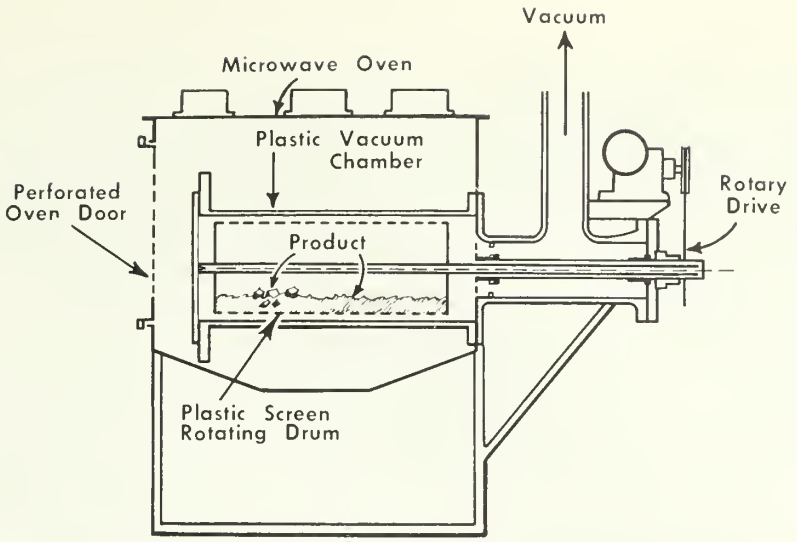

Figure 3.--Microwave-vacuum processing apparatus.

In order to reduce the overall cost of processing, conventional processing techniques must be used for as much of the process as possible. That is, microwaves should be used only to the minimum extent required to produce the desired effect.

The conventional process for making dried potato dice is well-known and has been described by Kueneman[1] and Feustel and coworkers[2] . Basically, the process involves peeling, dicing, washing, blanching, dipping in or spraying on a sulfite solution to prevent discoloration and drying. This process was used in all of the studies hereafter described. Russet Burbank, the variety usually considered most desirable for dehydration, was used exclusively. To further demonstrate the action of microwaves, dice, 3/4 x 3/4 x 3/4-inch, 1/2-inch french-fry cuts, and 3/8-inch shoestring cuts were used.

Conventional drying of potatoes can be carried out in tunnel, continuous-belt, or belt-trough dryers.[2] Typical drying temperatures range from 175° to 275°F. during the early stages. Rapid drying usually results in improved final rehydration. Since we wish to minimize the microwave energy consumed per pound of dry product, we must determine the most effective time in the drying process to introduce this energy. From the standpoint of efficiently reducing overall drying time, it would seem most logical to use the microwave energy in the very last stage. However, when we also require improved structure in the final product, we find that we must apply the microwave energy earlier in the drying period.

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[2]I. C. Feustel, C. E. Hendel, and M. E. Juilly. "Potatoes," Food Dehydration, Vol. II, eds. M. J. Copley and W. B. Van Arsdel, Avi Publishing Co., Westport, Conn., 1964.

As a piece of blanched potato dries it develops a case-hardened outer layer. The longer the drying continues, the greater will be the percentage of solids contained in this layer. If a piece of potato is conventionally dried to say 20 percent moisture and then exposed to microwave energy, the residual moisture in the wet core will be rapidly converted to vapor. If heating is done rapidly enough, the rate of vapor formation will be such that the dried piece will actually expand or puff. Unfortunately at this moisture content the case-hardened layer is developed to such an extent that most of the solids of the potato will either be in this layer or so closely bound to it that the expanded piece will be nothing more than a solid empty shell. Upon rehydration much of the interior will be open and contain little or no solid matter. At the other extreme, a very high-moisture piece will tend to be cooked rather than dried. Our results so far indicate that the most desirable end product is obtained if the potato dice are conventionally dried to about 40 to 50 percent moisture and then placed in the microwave tunnel. At this intermediate moisture level the case-hardened layer has developed to such an extent that the outer dimensions of the piece have been set, and yet a substantial portion of the potato solids remains in the wet core. When such a piece is rapidly heated by the microwave field, the internal vapor pressure exerts an outward force on the case-hardened layer and fissures develop between this layer and the internal material, as well as within the contents of the core. As drying proceeds further, shrinkage occurs from all directions within the piece, causing an open porous structure to develop.

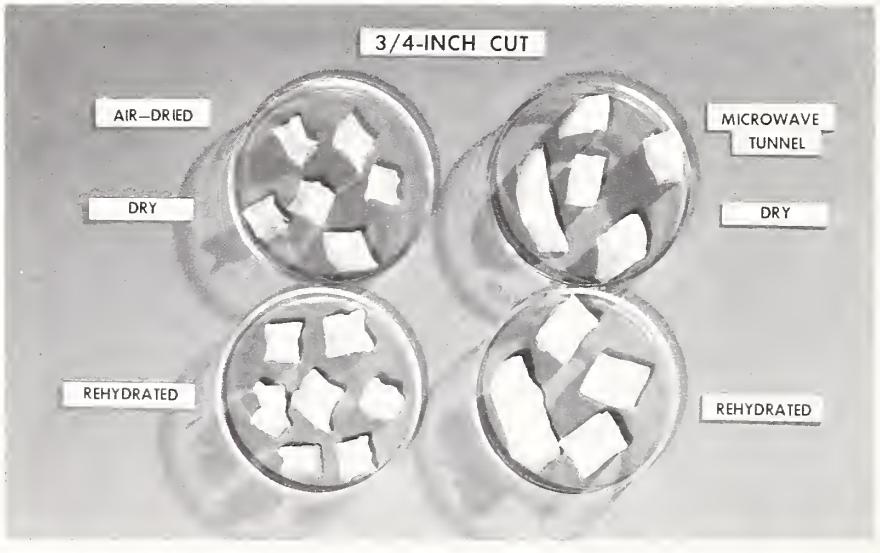

Figure 4.--Samples of conventionally air-dried and microwave-tunnel processed potato dice--3/4 x 3/4 x 3/4 inch.

Figure 4 shows samples of dried and rehydrated potato dice measuring about 3/4-inch on all sides. Note the difference between those samples which were conventionally air-dried and those which had the microwave treatment. In the dried form the conventionally dried samples are very shrunken, the sides are concave, and the pieces have a glassy, translucent appearance. The samples that received the microwave treatment have shrunk much less, the sides are nearly flat and perhaps even convex, and the pieces have a rather opaque appearance. After simmering in water for about 15 minutes, the microwave-treated samples have rehydrated to about 80 percent moisture, and their appearance approximates that of normal cooked potato. The air-dried samples do not rehydrate to nearly this extent in a comparable period, and they retain their concave sides with hard dry centers. The average moisture content of the pieces going into the microwave tunnel was about 47 percent, and the moisture of the pieces after microwave treatment was about 39 percent. Conventional tray drying was used for finish-drying to about 5 percent moisture. We could have used microwaves throughout the duration of the drying period; however, this would increase the power consumed above that necessary to produce the desired effect. During the microwave treatment, 150°F. air circulated through the sample at an average velocity of about 50 foot per minute.

Figure 5 illustrates the effects of using microwaves in combination with sudden pressure reduction to produce a porous product. The microwave treatment in this case involves placing the sample in the device depicted in figure 3, applying microwave energy, and after the product attains adequate temperature (about 210°F.), suddenly reducing the pressure within the chamber to about 50 mm. Hg. The sensible heat of the dice is suddenly converted to latent heat of vaporization at the lower pressure. The result is a porous product at a somewhat lower moisture content. Microwaves have some advantage in this type of process because the heat is generated within the piece where it is needed. However,in comparing the microwave-treated samples of figure 5 with those of figure 4, it can be seen that the pieces produced in the tunnel are very similar to those made by the vacuum process. We would therefore conclude that very little advantage is obtained for potatoes by using the vacuum technique.

Similar results were obtained with french-fry and shoestring cuts of 1/2-inch and 3/8-inch square cross sections. Rehydration was accomplished in about 10 minutes. Air-dried samples again showed poor rehydration, and the samples treated with microwaves in the tunnel were very similar to those made in the vacuum chamber.

From our results to date, I am optimistic about the future of microwave energy in dehydration processes. The results with

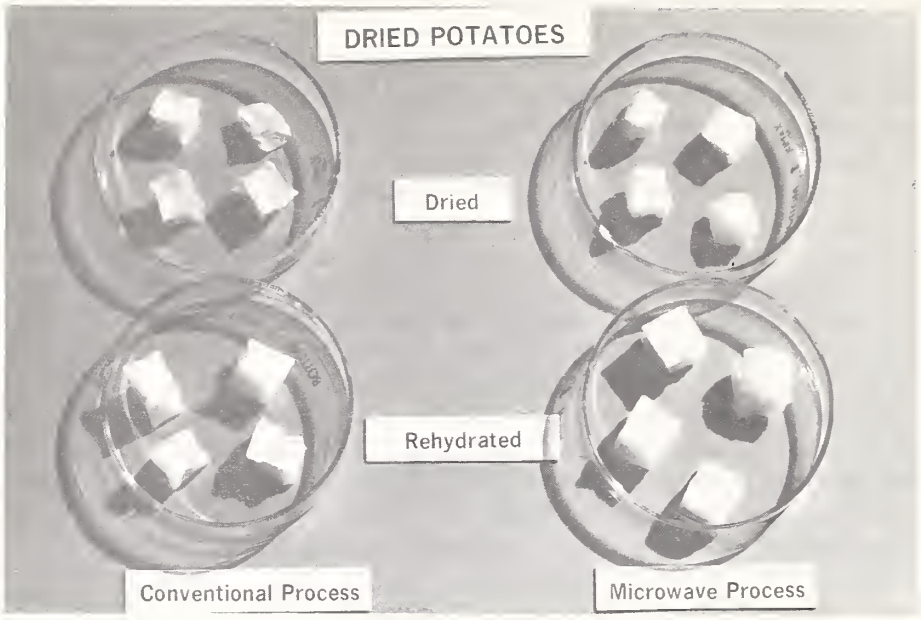

Figure 5.--Samples of conventionally dried and microwave-vacuum processed potato dice--3/4 x 3/4 x 3/4 inch.

potatoes are encouraging. We are in the very early stages of research and development with this form of energy. There are many avenues of approach, and perhaps more commercial development will be needed to determine the optimum alternative. In the meantime, I can assure you that we will make a worthy effort to develop and evaluate the application of microwave energy in these processes.

STARCH AND TEXTURE OF POTATO PRODUCTS

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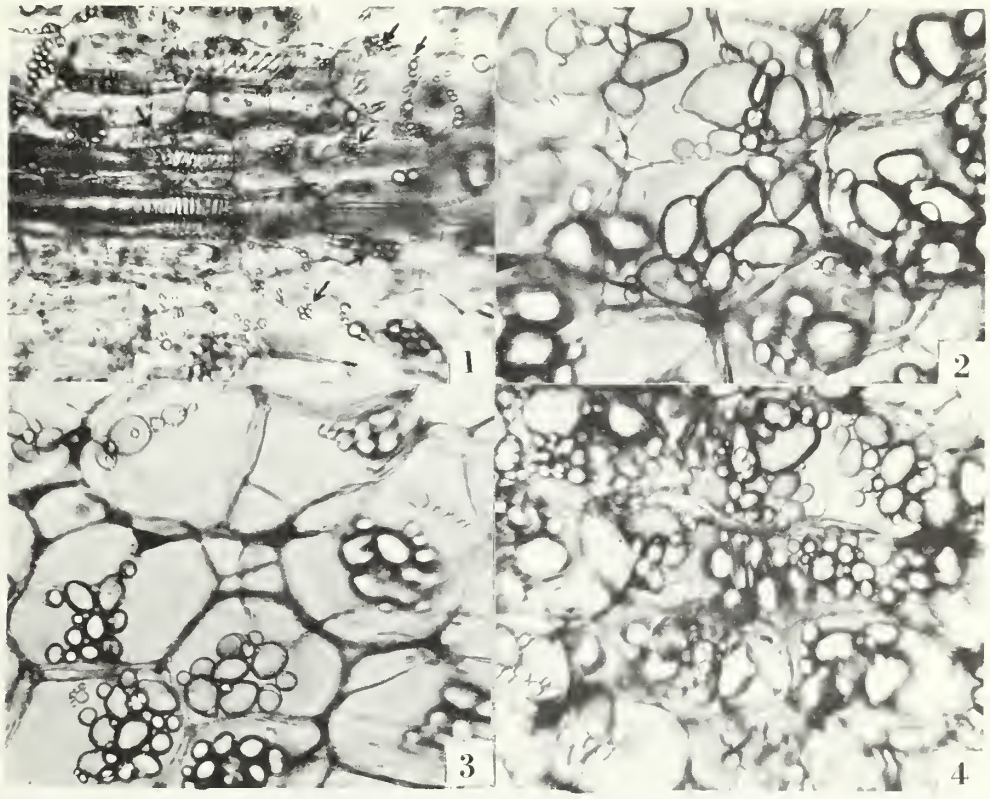
The textural qualities of potato products exhibit a remarkable range of physical properties that are difficult to measure mechanically with any degree of meaning or relationship to the cause of a particular quality. Cooked whole potatoes, for example, may be mealy in various degrees of dryness, or they may be waxy, soft, soggy, sticky, or gummy. The range from mealy to gummy consistency of mashed potatoes is further compounded by degrees

of lightness, or fluffiness, versus qualities of heaviness, or thickness, that are sometimes confused with simple stickiness. Even organoleptic distinction is not always easy and varies according to preference. Mechanical distinction usually requires special instrumentation for a specific textural quality.

A common basis for these texture differences is found in the variable effects of processing treatments upon the starch within the tissue cells. Fortunately, many of these effects can be observed microscopically both during and after treatment. It is thus possible to visualize the conditions responsible for a given textural quality. When a mechanism for change is thus established, further and more pertinent analytical and testing methods are suggested.



Figures 1-4.--(1) Vascular tissue areas (arrows indicate minute starch granules). (2) Inner storage parenchyma area. (3) Parenchyma of "water core." (4) Parenchyma of cortex. (All at 150X magnification.)

Native potato starch is not a uniform component. The starch granules vary greatly in size and their size distribution varies within different tissues in the tuber. A typical size distribution analysis of starch from whole tubers reveals that

over 50 percent of the granules are less than the average length of 28 microns (table 1). Many of the smaller granules from < 1 to 10 microns occur in the vascular tissue areas--the so-called "bundle ring" about 1/4 to 1/2 inch beneath the skin (fig. 1). The larger granules occur in the large storage parenchyma cells associated with the internal phloem, where they are most abundant (fig. 2), and in the "water core" or pith parenchyma, where they are least abundant and slightly smaller (fig. 3). Starch granules are very numerous in the somewhat smaller cortical parenchyma cells between the vascular bundle "ring" and the skin (fig. 4). This area contains the most starch per unit volume.

TABLE 1.--Size distribution of starch granules in Russet Burbank potato

Length Microns	Percent of total	Length Microns	Percent of total
< 9	11.2	50 - 59	6.9
10 - 19	27.2	60 - 69	4.2
[1]20 - 29	22.4	70 - 79	3.0
30 - 39	14.4	> 80	2.3
40 - 49	8.4		

[1]Average length = 28 microns.

Recent studies by Geddes and coworkers (1) in Scotland have demonstrated both an increasing average size of starch granules and an increase in the amylose-amylopectin ratio of the starch during tuber growth. These changes were further related to change in the fundamental properties of gels prepared from large and small fractions. Such relationships suggest possibilities in potato breeding for varieties of specific processing qualities.

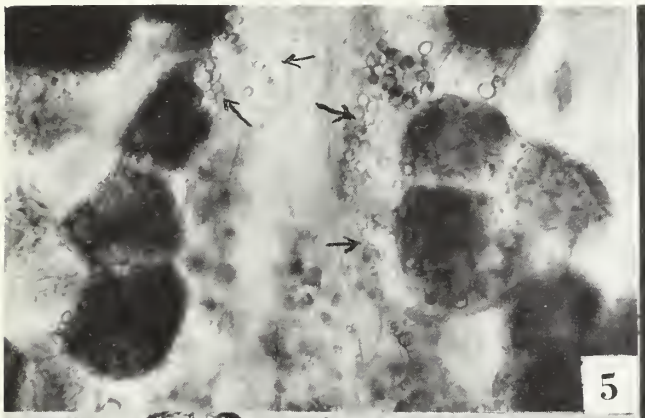
In addition, our studies have shown that starch-granule size distributions shift according to the temperature at which tubers are stored (table 2). A definite increase in average granule length is accompanied by reduced numbers of the smaller granules, which are digested and disappear more rapidly than the larger ones. Possibly, this shift, and the enzyme processes involved, also bear some relation to compositional difference between large and small granules.

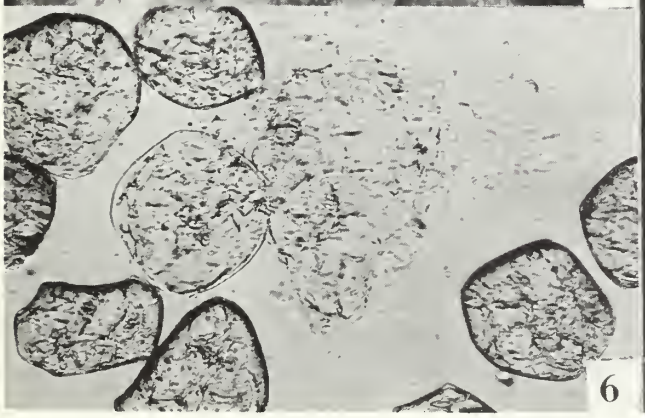
Smaller granules contain less amylose than the larger ones, which gel mostly between 60° and 65°C. (1). Slightly higher temperatures (65° to 70°C.) are required for gelation of the smaller granules (fig. 5). The gelation temperature is that at which the granules lose their optical birefringence in polarized light. With cooking at higher temperatures (190° to 212°F.), the gelled granules

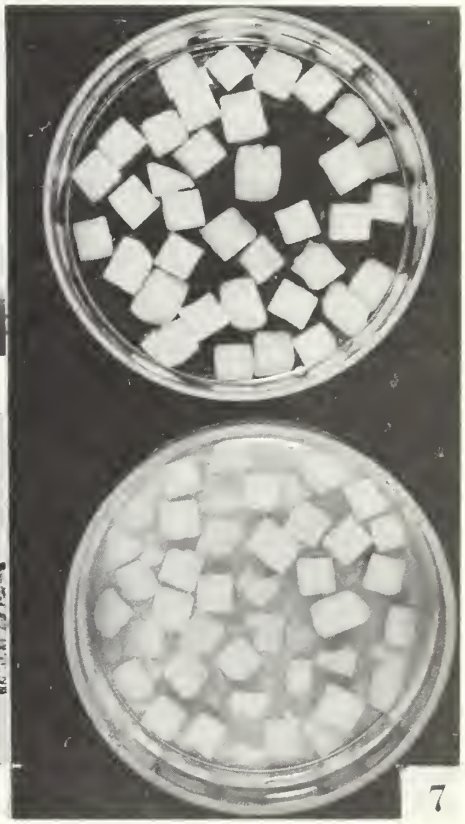
TABLE 2.--Influence of temperature upon starch granule size distribution in potatoes stored 2-1/2 weeks

Variety	Starch granules, size distribution	Storage temperature (°F.) 40°	50°	70°	80°
Kennebec	Avg. length (μ)	31	33	32	36
	< 15 μ (%)	20.5	18.4	15.5	12.5
Red Pontiac	Avg. length (μ)	26	30	33	--
	< 15 μ (%)	17.0	20.2	13.9	--
Russet Burbank	Avg. length (μ)	28	32	32	34
	< 15 μ (%)	25.5	17.0	17.1	15.0

continue to hydrate and swell and some of the soluble amylose diffuses out of the swollen gel. As swelling progresses, the tissue cells become distended and tend to separate because the middle lamellae (pectic cementing substances) between cell walls are at







Figures 5-7.--(5) Section heated at 65°C. for 1 hour (arrows indicate small, ungelled starch granules). (6) Separated cells of cooked, sloughed potato showing exudation of gelled starch from a ruptured cell. (7) Dice on left, precook heated 1 hour at 65°C., then boiled 45 minutes. Dice on right, boiled only.

least softened, if not degraded completely. Excessive swelling causes some cell rupturing and liberation of starch gel--a cause of stickiness in some dehydrated potato products (fig. 6). The liberated starch can be collected, stained with iodine, measured by reflectance densitometry (table 3), and otherwise characterized as to retrogradation and as to its complexing with glyceride emulsifiers such as are used to reduce stickiness (4), because both conditions influence color qualities obtained with iodine.

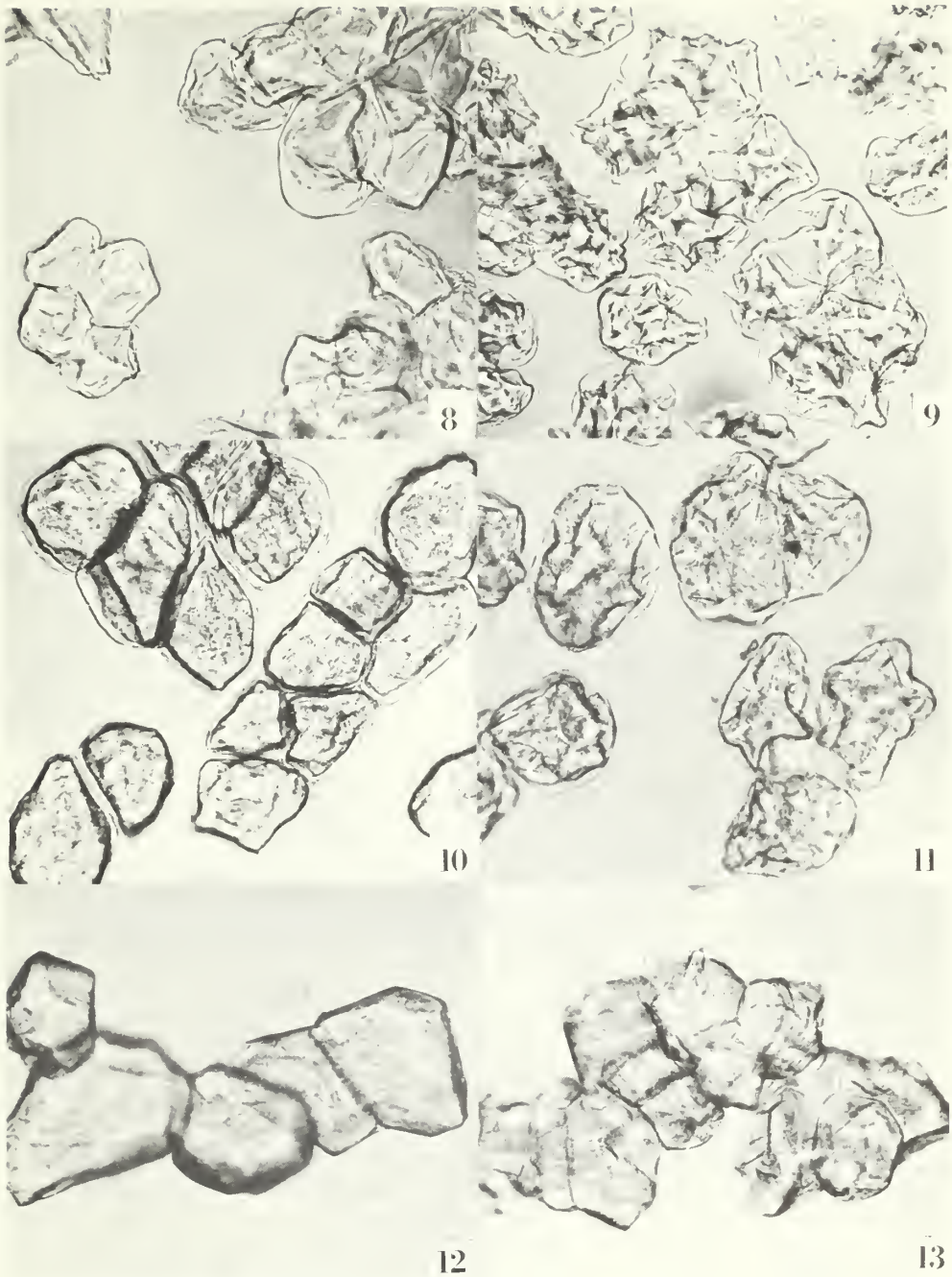
TABLE 3.--Reflectance and color characteristics of collected starches stained with iodine

Sample and preparation before collection	Color difference[1]		Reflectance density[1]
	A+(red)	B-(blue)	(log c/t)
2.5 mg. starch gelled at 180°F., then suspended at 150°F.	4.3	29.7	0.54
Plus 2.5 mg. glycerol monostearate	10.5	27.8	0.57
With sodium stearate	7.7	30.8	0.55
From granules suspended at 150°F., 18% cells ruptured	3.6	21.6	0.45
Plus 2.5 mg. glycerol monostearate	8.3	20.3	0.43
From granules suspended at 150°F., 1.5% cells ruptured	1.2	8.6	0.13
Plus 2.5 mg. glycerol monostearate	2.7	8.1	0.12

[1]Measured with Gardner color difference meter (4).

Retrogradation, the reassociation of the soluble straight-chain amylose molecules, reduces the water-absorbing capacity of the gel and has an appreciable effect upon the texture of potato products. When initiated by heating at 65°C. before cooking, retrogradation provides some control over sloughing by limiting the degree to which tissue cells are distended by the swollen starch gel (fig. 7). This, in turn is related to a reduction in amount of amylose dissolved with duration of precook heat treatment (3). Whittenberger and Nutting (6) found also that added sucrose increased the gel strength and the stability of potato starch at high and low pH. This may explain changes in cooking qualities of stored tubers in which sugars have accumulated.

Freezing and thawing, likewise, markedly affect starch gel properties by reducing the swelling capacity of gelled starch in cooked potatoes and, consequently, influencing the texture qualities of frozen potato products. Longreé (2) described these effects in cooked frozen potatoes and showed that, upon thawing, the starch gel remained shrunken and required a longer cooking period to return to the swollen condition characteristic of



Figures 8-13.--(8) Cells from frozen par-fry thawed 1 hour. (9) Cells from frozen par-fry after holding 3 days at 55°F. Figures 8 and 9 are thick glycerine mounts. (10 and 11) Cold (65°F. water mounts of figures 8 and 9, respectively. (12 and 13) Cells from the finish-fried products of 8 and 9, respectively, but mounted in paraffin oil. (All at 100X magnification.)

freshly cooked potatoes, and to overcome the "dry cottony" texture of frozen and recooked potatoes. Very similar conditions were described by Spiruta and Mackey (5), for frozen par-fried potatoes, in relation to texture in the french-fried condition. These findings have been confirmed and extended in our studies on french fries. Cells from the interiors of frozen par-fries thawed 1 hour at room temperature, when mounted in thick glycerine to avoid rehydration, have a shrunken, raisinlike appearance (fig. 8). Cells from frozen par-fries, thawed and held 3 to 5 days at 55°F. to simulate some of the institutional holding conditions, are even more shrunken in appearance (fig. 9). When soaked 10 minutes in cold water (65°F.), the cells from the par-fries thawed 1 hour, swell somewhat. Their cell walls swell more rapidly than their gelled starch. Their starch contents assume some of the characteristics of freshly cooked potato. In potatoes not cooked to the point of cell sloughing, the tissue cells remain angular and polyhedral as in their original raw state (fig. 10). Cells from thawed samples held at 5 55°F., however, are obviously slower to rehydrate in water and remain more irregular and shrunken in appearance (fig. 11). Similar differences are apparent upon examination of interior cells after finish frying. The cells from french fries thawed only 1 hour in the par-fry condition have a smoother, more uniform polyhedral shape (fig. 12) than those from the products produced from thawed par-fries held several days at 55°F. before finish frying (fig. 13).

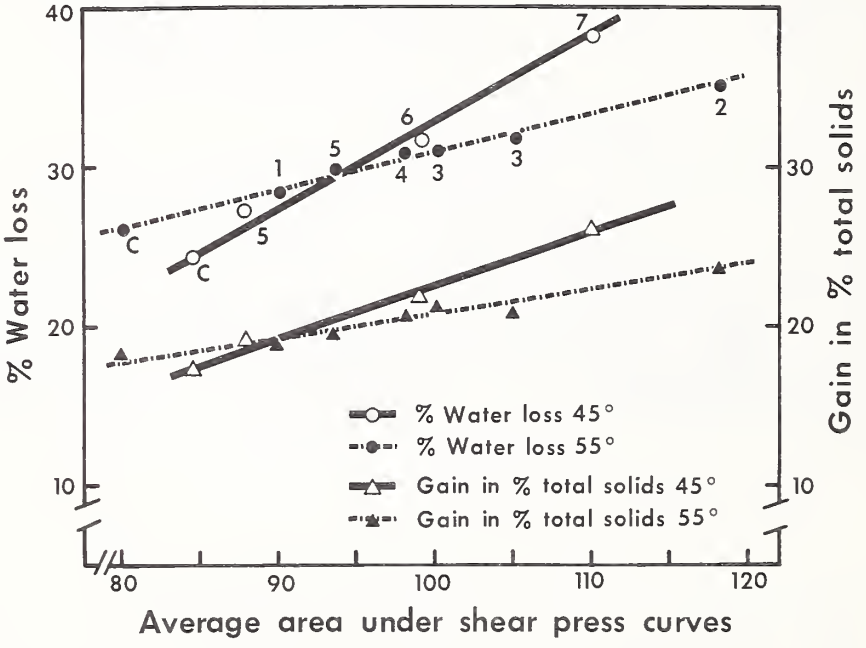


Figure 14.--Influence of water loss during finish frying upon shear-press values. Numerals refer to number of days held at 45° and 55°F.

Prolonged holding of par-fries at above-freezing temperatures also results in an increase of fat absorbance upon finish frying. This increase may be as much as twice that absorbed by par-fries thawed for only 1 hour. There also are distinct increases in total solids gained, or in percent of water lost, upon finish frying as a result of prolonged holding after thaw. These increases are reflected in shear-press measurements and are inversely related to duration of holding at 55°F. (fig. 14). They were directly related to holding time for par-fries at 45°F. within the intervals investigated. Both situations suggest influences of time and temperature upon gelled starch properties, such as changes in water-absorbing capacity.

These examples only briefly survey the role of starch in texture of potato products. Control of texture through manipulation of starch gel properties has been applied to some degree in the technology of flake and granule manufacture. Possibilities for such manipulation in the manufacture of other potato products are considerable but scarcely have been approached. Likewise, fundamental studies on composition and properties of different potato starches may provide valuable information for development of varieties suited more specifically to certain processing requirements.

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PACKAGING AND POTATOES

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Packaging is related to almost all phases of business can make many contributions. One important area includes economies and efficiencies in the customer's plant and his distribution system. Here we are not only concerned about the cost of materials but also such factors as labor costs, mechanical packaging lines, floor-space utilization, materials movement, inventory control, and warehousing efficiencies. Appropriately, all of these elements can be integrated into the technical packaging system. Studies and evaluations of the currently employed system by competent structural designers, engineers, and other specialists may produce opportunities for cost savings and additional efficiencies.

In the marketing and merchandising area, packaging may contribute to increases in sales, improvements in retail price, expansion in distribution, successful introduction of new items, revitalization of existing brands and products, and enhancement in total corporate identification.

Successful packaging solution builds on a broad information base developed with the aid of market research. Many sources of information and many research techniques can be employed to complete information requirements. Information is then translated into design ideas with emphasis on graphics or three-dimensional concepts or promotional ideas in display, premiums, direct mail. This process of design translation must take into account the practical limitations of available machinery and cost needs. Successful packaging solutions always rest on the pillars of research, design, and production.

The structural and visual components of effective packaging will take into account the consumer's need for variety, quality, and convenience, and the retailer's expectation of efficiencies in handling and effective shelf-display. Many packaging materials, because of their adaptiveness, lend themselves to the addition of many values and services. Unfortunately, in the potato industry, not a very outstanding job has been accomplished in packaging so far. The industry suffers from an inferiority complex about its product and has based many of its packaging decisions on cost rather than service considerations. Any product, even widely used staple products, can be glamorized. In the potato business in particular a considerable job of upgrading the merchandising presentation could be undertaken. Packaging is not a production

expense but a marketing investment. Its creative use helps build brands, and brand-building leads to consumer acceptance and market control. Apart from an orientation to cheaper materials, some of the pitfalls to guard against in potato packaging are poor brand identification, imitation of competitive designs, inadequate translation of appetite appeal potentials. Quite obviously, a tremendous opportunity lies ahead for the industry.

To attack the marketing problem, it would be wise to periodically review with professional sources technical as well as marketing concepts represented by current packaging systems. Because of continuous competitive activity, these systems will have to be evaluated against developments by competitive sources. Surely these investigations will produce a continuous stream of opportunities for potato packers and marketers to increase their role in the market place and, with the use of good packaging, to make their businesses more prosperous and profitable.

POPULATION, TRANSPORTATION, IRRIGATION, AND POTATO ECONOMICS

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I have decided to present four separate but interrelated subjects. First: Projections of potato utilization to 1975. These will be made on per capita consumption based on census projections of population. Second: Minimum-cost transportation models will be presented for some processed potato products. From these linear programming models, marginal costs of transportation between production areas can be determined. Third: From a conceptual point of view, I will discuss policies which should govern Federal development of irrigation facilities. Fourth: I will present in conceptual form a potato utilization model. The question we are seeking an answer to is "Can we maximize total returns from any given size crop by utilization allocations?"

Because of time limitation aggregated data must be used and the ideas conceptualized rather than presented in detail. However, relevant detailed work has been done on each of the ideas and appropriate citations are listed.

Projections of potato utilization to 1975.--The data I will present are not unique. However, I want to present the data again as background for my transportation models and the economic utilization model. Considering only human food utilization from 1956 to 1964, around 213 million cwt. of potatoes would have been needed in 1965, 240 million will be needed by 1970, and 272 million by 1975. Based on census projections of population, 12.7 percent more potatoes will be needed by 1970, compared to 1965, and 28 percent more will be needed in 1975. By 1975 the U.S. population will be around 235 million people; however, the acres planted to potatoes will probably continuously decrease, because yields per acre are increasing at a greater rate than population.[1]

The most significant aspect is the form in which these potatoes will be used. Using per capita consumption trend lines for fresh potatoes compared to processed, processing will bypass fresh consumption by the 1972-73 crop year. Remember that this is a mathematical projection of past trends, not a prediction. The simple point is that the future location of potato production will be those areas that can produce, process, and transport processed potatoes to market the most efficiently. This leads us conveniently into the next topic.

Minimum cost transportation models for potatoes.[2]--I have chosen to present models only for processed potatoes, and of processed potatoes, only for frozen and dehydrated products. These are distributed regionally or nationally from plants while chips are mostly distributed locally. The development of microwave potato chip frying is likely to intensify efforts of chippers to procure local supplies of raw potatoes. Further, location of chip processing is likely to remain market-oriented rather than raw-product-oriented for some time.

The easiest way for me to view a minimum-cost transportation model, say for frozen french fries, is that if one man were in charge of distributing all production in the U.S., what would be the least-cost system of distribution? For a transportation model with each state as a market, the following data are needed: total production of frozen products in each state, consumption in each state, and freight rates from each surplus-producing state to each of the other 47 states. For frozen potato products, I used unofficial estimates of production (table 1).

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[1]U.S. Department of Commerce, Series II Population Projections (1963).

[2]For a more detailed discussion of transportation models, see W. Smith Greig, "Locational Effects of New Technologies in Fruit and Vegetable Processing," Mich. State University Agr. Expt. Sta. Res. Rpt. 35, 1965.

TABLE 1.--Quantities of frozen potatoes processed by states, 1965 crop year

State	Potatoes utilized in frozen form in 1965	
	Raw product equivalent (cwt.)	(60% yield) (cwt.)
Idaho	14,900,000	8,940,000
Maine	7,500,000	4,500,000
Washington	2,900,000	1,740,000
Michigan	1,800,000	1,080,000
Red River Valley	800,000	480,000
Total	27,900,000	16,740,000

For consumption data, I assumed a standard per capita consumption. Each state consumed an amount relative to its population. For transportation costs, minimum carload rail rates, which were obtained from a national freight rate consultant, were used. The model assumes that consumers accept the products from different states as perfect substitutes.

The minimum-cost distribution system for frozen potato products for the 1965 crop would be as shown in figure 1. Under this system, the total freight bill would be $23,853,650 and no other system of allocation would cost less. By the use of this model, we can determine the cost of transportation of the last unit to be shipped from each state. This is called the marginal cost of transportation. We can then compare these marginal costs between producing states to get an idea of comparative advantage. In this model, Michigan has the lowest relative marginal cost followed by Maine, the Red River Valley, Washington, and Idaho. If the last 100 pounds of raw product processed in Idaho were shifted to Michigan, the savings in freight costs would be $0.87 (table 2). To make comparisons of marginal transportation cost

TABLE 2.--Frozen potato products: Relative marginal transportation costs per 100 pounds' raw product equivalent[1]

State of origin	Marginal freight cost[2] (Dollars per cwt.)
Michigan	0.00
Maine	.15
Red River Valley	.18
Washington	.78
Idaho	.87

[1]Assumes a 60 percent product weight yield.

[2]The difference between any of these relative marginal costs is based on the deviation from optimum solutions and is absolute in nature. They show the reduction in aggregate costs that could be made by shifting 100 pounds of raw product from the state of higher cost to the one of lower cost.

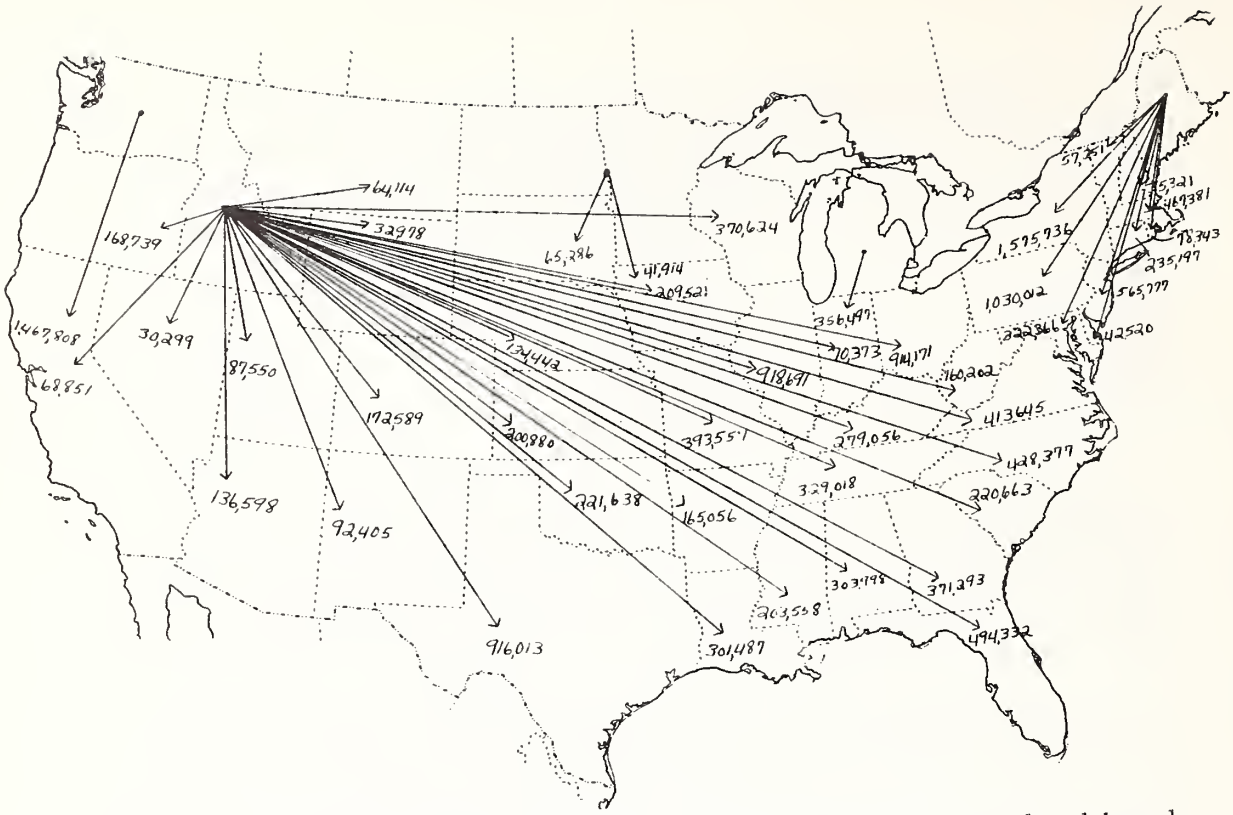

Figure 1.--Frozen potato products. Numbers are 100 pounds shipped.

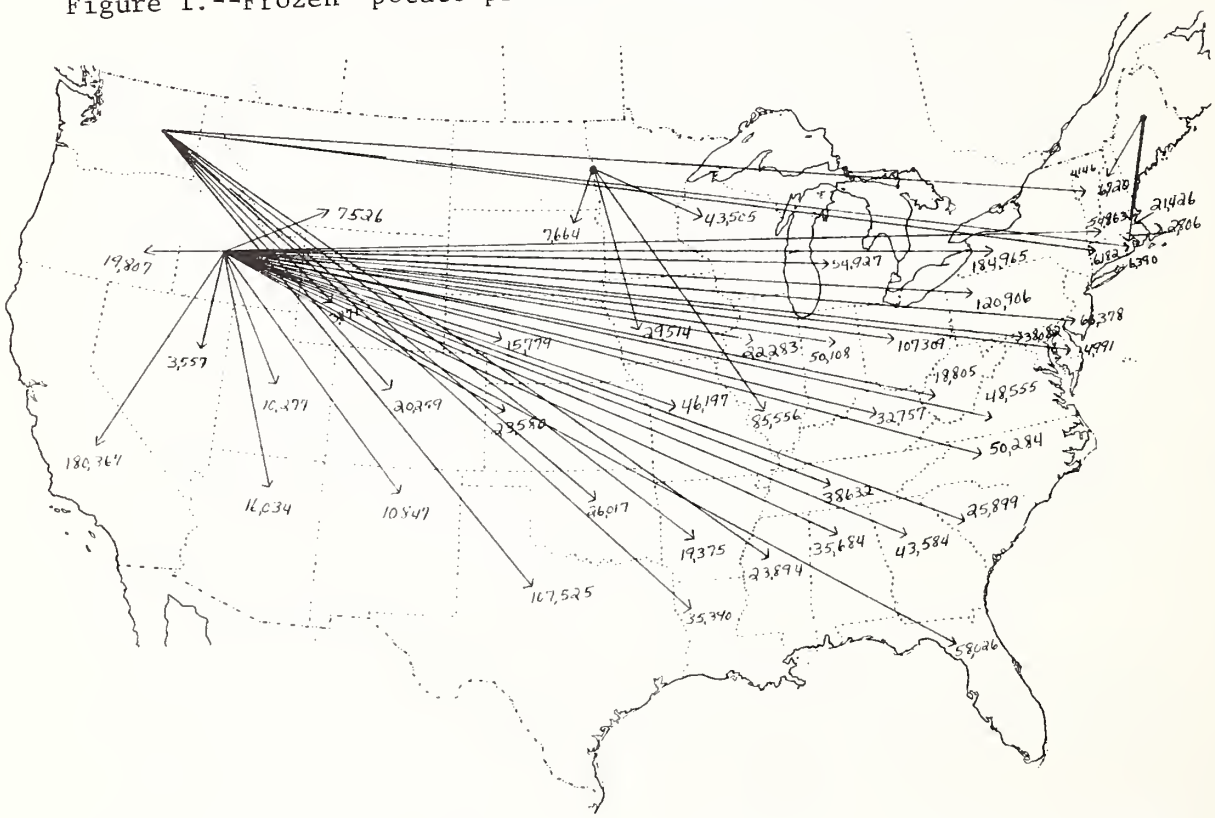

Figure 2.--Dehydrated potato products. Numbers are 100 pounds shipped.

differences, simply substract the lower cost from the higher cost in table 2. This is then your savings in marginal freight costs.

Now, those who have followed this discussion should have picked out at least two glaring weaknesses: (a) There is not a perfect market in frozen potato products, since quality of products differs among regions and (b) individual processors certainly do not conform to the model suggested. Each one sells his products anywhere he can. My argument here is that the closer processors approximate the model, the less the freight costs and the greater the profit. Concerning quality, processors must decide whether quality and other cost differences more than offset the freight cost differentials. My personal view is that processing techniques are becoming so sophisticated that quality differentials are becoming less and less important.

A transportation model for dehydrated mashed potatoes is quite similar to the one for frozen potato products, although freight costs are much lower (on a raw product equivalent basis), and the relative marginal costs between States are much lower. For dehydrated mashed potatoes, the unofficial 1965 crop year data (table 3) were used. These data yielded the transportation model

TABLE 3.--Quantities of dehydrated mashed potatoes produced by states, 1965 crop year

State	Raw product equivalent	Estimated production of dehydrated (15 percent yield)
	(cwt.)	(cwt.)
Idaho	9,100,000	1,365,000
Washington	1,900,000	385,000
Red River Valley	1,400,000	210,000
Maine	500,000	75,000
Michigan	200,000	30,000
Total	13,100,000	1,965,000

shown in figure 2. The marginal costs among surplus producing states were lowest in Maine, followed by the Red River Valley, and Idaho and Washington were tied with the highest marginal costs (table 4). Michigan is still a deficit-producing State and only surplus-producing States were included in the model. If Michigan's marginal costs were included, they would be around 40¢ less per cwt. than those of Idaho and Washington and around 20¢ less than those of Maine. From table 4, a shift in using 100 pounds of raw potatoes in Maine rather than in Idaho or Washington would result in a saving in freight costs of around 19 cents. Again, as in the case of frozen products, there may be other major cost or quality differences that more than offset this transportation cost differential. In

general, although I did not have access to freight rates for fresh potatoes, the differentials, I believe, are slightly higher than for frozen potato products.

TABLE 4.--Dehydrated potato products: Relative marginal transportation cost per 100 pounds raw product equivalent[1]

State of origin	Marginal freight cost[2]
	Dollars per cwt.
Maine	0.00
Red River Valley	.10
Idaho	.19
Washington	.19

[1]Assumes a processed product weight of 15 percent raw product weight.

[2]The difference between any of these relative marginal costs is based on the deviation from optimum solutions and is absolute in nature. They show the reduction in aggregate costs that could be made by shifting 100 pounds' raw product from the State of higher cost to the one of lower cost.

A question I was asked to answer was, "Do freight rates from the West provide a price umbrella for other regions?" The answer is yes, they do to certain markets, but you must define the market you are talking about. Secondly, you have to define the product you are talking about. The Maine transportation umbrella at the marginal areas of distribution is around 20¢ per 100 pounds of raw product for dehydrated, 62¢ for frozen french fries and perhaps 75¢ to $1 for fresh potatoes. The Red River Valley transportation umbrella is slightly greater than Maine's and Michigan's transportation umbrella is greater still.

Federal development of new irrigation facilities for Western potatoes.[3]--Related to the rapidly expanding western production of potatoes for processing is the underlying question of water and Federal reclamation and irrigation projects. Should the Federal government bring new areas into production to compete with the older established areas? Let's explore this question. The issues involved in Federal reclamation of western lands are not new. As early as 1927 the Secretary of Agriculture was outspokenly against bringing more irrigated lands into use. In 1930, the Secretary of Agriculture wrote "Our national reclamation policy should be reconciled with the need for restricting farm production." He charged that the reclamation program involved a direct subsidy to Agricultural expansion in the form of interest-free loans. This subsidy policy seems inconsistent with the efforts now being made

[3]I am indebted to Dr. Milton Steinmueller, Dept. of Resource Development, Michigan State University, for suggestions on this section.

by the Federal government to restrict agricultural production.[4] In an excellent review of the Economic Demand for Irrigated Acreage, Ruttan[5] in 1964 questioned our current policy of the Department of Agriculture on one hand trying to take 25 to 30 million acres of land out of production by the use of acreage allotments and soil bank programs, while on the other hand the Bureau of Reclamation in the Department of Interior is actively involved in bringing new irrigated lands into production. In fact, production from the 7.2 million acre increase in irrigated lands between 1949 and 1959 just about accounted for the loss in production from the 25 to 30 million acres of land taken out of production through Department of Agriculture programs. With the very evident conflict in policies, just what are the issues involved and can the issues be resolved? In the broadest sense the issue is that of efficiency compared to equity.[6] Efficiency, as used here, is a national concept while equity is a localized or regional concept. Efficiency implies that certain activities in reclamation are undertaken in order to maximize the net economic returns (goods and services) to the Nation as a whole. Where Federal funds are involved, the reclamation project, compared to all other possible projects, would provide the largest amount of goods and services to the Nation. Equity is a concept of social and human values. Reclamation projects are undertaken to provide farms in under-developed areas, to provide employment in times of depression, to raise standards of living in depressed areas, to provide regional economic activity.

Although it is decidedly unpopular to be "against" the equity issues or "against" the issues of "social and human values" associated with a reclamation project, as an economist I must place more weight on the efficiency aspects of reclamation. In each project then the question becomes "do net returns from the project exceed the cost?"

The method of calculating costs and returns is typically called a "cost-benefit" analysis. Analysis of new reclamation projects should take into account domestic, municipal, or industrial water supply, irrigation, water quality control; navigation,

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[4]Donald C. Swain. Federal Conservation Policy 1921-1933. Univ. California Publications in History, Vol. 76, Univ. Calif. Press, p. 86, 1963.

[5]Vernon W. Ruttan. The Economic Demand for Irrigated Acreage. The Johns Hopkins Press, Baltimore, Md., p. 9, 1964.

[6]Irving K. Fox. National Water Resources Policy Issues Reprint No. 4, Resources for the Future, Inc., 1145 Nineteenth St., N.W., March 1958, Washington, D.C. 20025.

John V. Krutilla. Welfare Aspects of Benefit-Cost Analysis Reprint No. 29, Resources for the Future, Inc., June 1961.

hydroelectric power, flood control and prevention, land and beach stabilization, drainage (including salinity control), outdoor recreational development, and fish and wildlife development.[7] In justifying reclamation or irrigation projects, how should costs be allocated among these objectives? How much do you decide to charge for irrigation uses and for recreation uses? In an "economic" analysis, can you charge off more costs to electricity users and reduce the cost of irrigation water to farmers? While there are inherent difficulties in evaluating irrigation costs and the returns from irrigation, this can be and has been done.

Ruttan has cited data to show that the annual amount farmers pay to irrigate land under Federal projects in nine western resource regions is well under one-half the total costs if the projects were fully amortized (table 5). There is a tremendous amount of methodological work underlying Ruttan's analysis. For a detailed understanding of the problems involved, I suggest you read his complete report. This brief summary is given to indicate one researcher's estimate of the costs and returns from Federal irrigation projects. The marginal value of production of crops from these Federal projects, according to Ruttan, is less than the fully

TABLE 5.--Comparison of irrigation costs and productivity estimates[1]

Region	Charges paid by farmers	Fully amortized costs	Marginal productivity
	Dollars[2]	Dollars[2]	Dollars[2]
Pacific Northwest	44.26	80.56	63.32
Central Pacific	67.22	108.51	91.14
South Pacific	116.11	275.58	418.16
Colorado River	44.59	122.09	17.13
Great Basin	20.42	70.87	30.84
Upper Rio Grande and Pecos	40.35	82.41	79.12
Western Gulf	53.02	94.98	92.86
Upper Arkansas White-Red	28.86	93.98	83.58
Upper Missouri	24.89	89.09	58.87

[1]Source: Vernon W. Ruttan. The Demand for Irrigated Acreage The Johns Hopkins Press, Baltimore, Md., 1965.

[2]Per acre per year.

amortized costs in all of the Federal projects except the Southern Pacific Region. However, in most cases the marginal value of the

[7]"Policies, Standards, and Procedures in the Formulation, Evaluation, and Review of Plans for Use and Development of Water and Related Land Resources." The President's Water Resource Council, Senate Document No. 97, 87th Congress, 1962.

products from an acre of irrigated land is usually much greater than the amount the farmer pays for irrigation from the Federal projects. From an economic point of view, then, the Federal irrigation projects apparently cannot pay the fully amortized cost, but they do pay the farmers because the farmer pays much less than the amortized cost. Thus, nearly all the Federal irrigation projects are subsidized by the Federal taxpayer, many to the extent of $40 to $50 per acre per year.

Federal subsidy for irrigation is not a unique social benefit. We can list subsidies to many kinds of enterprises in the United States: airports, highways, railroads, steamship companies. Restrictions on manufactured imports are also a subsidity to domestic manufacturers. Even so, from the standpoint of an economist and from the standpoint of national efficiency, I would suggest that new Federal reclamation projects should be undertaken only if returns exceed the fully amortized costs. Now to answer the question, Should Federal funds be spent for new reclamation projects where potatoes can be grown? My answer would be: yes, only if the farmer pays the fully amortized cost for receiving the land and irrigation water. Any other system is a direct subsidity by taxpayers to the new producers, and certainly does not fall under the definition of efficiency of use of Federal funds.

Despite the negative results of many economic studies, Federal irrigation and reclamation projects will probably continue at a rapid rate. It is interesting to note that while the beneficiaries of reclamation development projects in the West under the Department of Interior at least pay part of the costs, the recipients of benefits of "flood control" projects in the Eastern and Southern United States undertaken by the Corps of Engineers generally pay no part of the costs.[8] Irrigation sometimes results from these Eastern and Southern "flood control" projects.

Among the dreams of the future is the North American Water and Power Alliance.[9] This project being studied by the U.S. Senate Public Works Committee would divert water from Canada and Alaska to the North Central and Western parts of the U.S. and on into Mexico. NAWAPA, as it is called, would cost $80 billion and store over 4.3 billion acre feet of water. Under this project, Mexico,

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[8]See Irving K. Fox in footnote 6.

[9]Western Water Development--A Summary of Water Resource Projects, Plans, and Studies Relating to the Western and Midwestern United States, U.S. Senate Committee on Public Works, U.S. Government Printing Office. 1964.

alone could irrigate more than eight times as much land as the Aswan High Dam will provide Egypt. I would not doubt that this project or one as extensive will be undertaken in the lifetime of some of the people in attendance here today.

Maximizing total returns by an economic utilization model.[10]-- It is well known that potatoes at the farm level have an inelastic demand. The elasticity of demand is a measure of the percent change in quantities sold associated with 1 percent change in price. With an inelastic demand, greater total dollar sales result from reducing supplies, but with an elastic demand greater total dollar sales result from increasing supplies. With an inelastic demand, the total value of a small crop of potatoes is much larger than the total value of a large crop. For example, the 197-million-hundredweight fall crop in 1963 was worth 332 million dollars, but the 172-million-hundredweight crop in 1964 was worth 625 million dollars. A less well-known fact is that while fresh potatoes at retail have an inelastic demand, processed potatoes at retail have a highly elastic demand. Again, the elasticity of demand is merely a measure of price-demand relationships. Because of the differences in demand elasticities of potatoes and potato products at retail, it is possible to increase total sales value of any given size of crop by controlling the allocation of any specific crop to fresh market and to processing utilization.

More specifically, several studies have shown fresh potatoes to have an elasticity of demand around -0.4. Or a change of 10 percent in quantities produced results in about 25 percent change in price in the opposite direction. However, one study of dehydrated mashed potatoes indicated an elasticity of demand of -2.3, or a 10 percent change in quantities results only in about a 4 percent change in price in the opposite direction.[11] Basically then, if supply of fresh potatoes is restricted, total returns are increased, but to increase total returns of processed potatoes, quantities to be sold should be increased. Undoubtedly frozen french fries and potato chips have demand elasticities much greater than unity. Oddly enough in a study of dehydrated mashed potatoes, there was practically no cross elasticity of demand between dehydrated mashed and fresh potatoes. These products (in 1958) apparently operated on completely independent demand schedules. I am sure this is true

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[10] For more detail, see W. Smith Greig, Maximizing Total Dollar Sales of Apples and Apple Products by a Utilization Model, Mich. State Univ. Agr. Econ. Mimeo. 889, August 1962.

[11] W. Smith Greig. Relative Retail Sales and Elasticity of Demand for Dehydrated Mashed Potato Products, Mich. State Univ., Agr. Econ. Mimeo. 732, July 1958. W. Smith Greig, Adapting to Change, talk given at the First National Apple Utilization Conference, College Park, Md., March 23, 1966.

for potato chips, but I would guess that by now there are some cross elasticities of demand between frozen french fried, dehydrated mashed potatoes, and fresh potatoes. (These latter products probably do compete with fresh potatoes to some degree.)

Some agricultural industries, notably the dairy industry, have used the differences in elasticities of demand among products quite effectively. The amount of milk going for fresh fluid milk is restricted and this segment brings a premium price. The rest of the milk is placed at a discounted price in cottage cheese, butter, cheese, etc.--products with much higher demand elasticities. By this process a much higher total return is obtained than if there were no market allocations.

An approach to a utilization model for potatoes would first be research to isolate the demand elasticities for different products: fresh, chips, frozen french fries, dehydrated mashed, starch, etc. Then for any given size of crop, a formula could be applied to give maximum total returns for the crop. For example, the objective might be a fall crop total value of 400 million dollars a year. (This can be obtained; it was obtained in 1964.) Quantities of fresh potatoes could be restricted to average, for example, $4 per 100 pounds, processing potatoes might sell for $2 per cwt., and starch and livestock feed at $0.50 per cwt. Different prices would be charged for different methods of utilization based on the economic-price-demand relationships. The total funds for the sale of all potatoes would go into a national holding fund and be reallocated, based on average price of all potatoes sold. Each grower would sell to the utilization method specified but would receive payment for average prices received for all utilization methods of the total crop. Of course, there would be premiums for quality and discounts or premiums from average based on freight costs.

Inherently this is no different from General Motors Corporation's allocating production between Cadillacs and Corvairs, or the milk industry's restricting quantities of milk going into fresh fluid milk and placing the rest in processed utilization forms. The utilization program would not be a control program in the sense of acreage allotments or production restrictions, but only in the most economic allocation of utilization method of any given sized crop. Areas would still compete in a true economic fashion.

I have decidedly been a critic of past proposals for national market orders and agreements for potatoes in that I have felt that the orders would tend to stabilize production where it currently is and prevent much effective competition between areas. The program I am suggesting and which I feel merits attention would merely be the most economic utilization of any given crop based on true

price-demand relationships, with no restrictions on competition between areas of production.

Summary.--Projections of methods of utilization suggest processing utilization will bypass fresh utilization of potatoes in the U.S. by 1972-73. The future location of potato production will be those areas that can produce, process, and distribute processed potatoes most effectively. Transportation programming models suggest significant transportation cost differentials among producing States in frozen french fries and lesser differentials in dehydrated mashed. The Western transportation costs range as high as 87 cents per 100 pounds of raw product equivalent above Midwestern and Eastern costs for frozen french fries and from $0.19 to probably $0.35 to $0.40 above Eastern and Midwestern transportation costs for dehydrated mashed potatoes. Fresh potato transportation differentials are probably higher than for frozen french fries. There are definite transportation cost "umbrellas" among regions. A basic unanswered question is 'Do other costs more than offset these transportation umbrellas?' New Federal reclamation projects for potatoes should be developed only if the fully amortized costs of the projects are charged to the user. Some recent data show that Federal irrigation projects charge less than half of the total costs to the users.

Finally, I have suggested that a national economic utilization model be developed and be used by the potato industry to maximize total returns for any size of crop. In this model, potatoes would be allocated to utilization forms based on economic price-demand relationships. The basis of this model is the widely different demand elasticities for fresh and processed potatoes at the consumer level.

THE WASHINGTON POTATO INDUSTRY: PAST, PRESENT, AND FUTURE

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Many words have been spoken and written about the Washington potato industry. Past State and national potato utilization conferences have included sections dealing with various aspects of it. Processors may be interested in the high yields per acre and in the high specific gravity of Washington's potatoes. Producers in other potato areas may be interested because of the potential for expansion in Washington and the competition for markets posed by this expansion. Research people may be interested in Washington's industry because potatoes have been long regarded as a cool-season crop yet they produce record yields in the Columbia Basin with temperatures in the nineties. The United Fresh Fruit and Vegetable Association's Fruit and Vegetable Facts and Pointers on Potatoes, for example, concluded that "The potato is a cool weather crop but can't stand much frost. Well distributed moderate rainfall or irrigation is needed. Studies of climatic requirements of the potato by many workers has led them to the conclusion that maximum yields are obtained with growing-season temperatures averaging between 60° and 65°F. (some say between 65° and 70°F.). High temperatures are unfavorable. One theory is that excess temperature interferes with the growth of the tubers by favoring a rapid rate of respiration in the aboveground part of the plant." Washington's Columbia Basin may indicate a revision of this widely held belief.

The Bureau of Reclamation is interested in the ability of Columbia Basin farmers to pay irrigation project construction, operation, and maintenance costs. And finally, private investors are interested in the potential profits from deep-well and river pumping irrigation of large areas of remaining fertile but arid land in the South Central area of Washington.

A brief glimpse at the statistics indicates that the potato industry is no newcomer to Washington. They have been produced commercially there for almost 70 years. At one time in the 1920's Washington was the largest producer of Russet Burbank (netted gem) potatoes.[1]

Records also show that 64,000 acres of potatoes were harvested in Washington in 1922. Potato acreage trended downward from 1922 to a low of 26,000 in 1952. Since 1952 potatoes have

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[1]Opportunities and Advantages for Potato Processing in The State of Washington, Résumé of Washington State Potato Facts, prepared and distributed by the Washington State Potato Commission, 111 Pierce Ave., Yakima, Wash.

shifted out of the Yakima Valley and Western counties into the Columbia Basin. Along with this change in location there has occurred an increase in acreage. In 1965, 50,000 acres were harvested, 42,000 acres of which were located in the Columbia Basin. The estimate for 1966 is 58,000 acres with about 50,000 acres in the Columbia Basin. Thus, the total expansion of 8,000 acres in 1966 will occur in the Columbia Basin.

In 1922 the State's average potato yield was 99 cwt. per acre, about 5 tons. Yields remained at about this level until 1940. From 1940 to 1946 yields trended upward toward 168 cwt., or 8 tons per acre. Since then they have increased rapidly. In 1965, the State's average yield per acre was about 355 cwt.--almost 18 tons. Fall potatoes in the Columbia Basin in 1965 averaged 395 cwt. per acre, almost 20 tons.[2] These late or fall potatoes comprise one-half to two-thirds of the total crop in the Basin. Research results indicate up to 1,000 cwt. or 50 tons are possible under ideal conditions.

One of the most significant developments in the potato region of Washington in the past 2 years is the increase in proccessing facilities and in storage structures. There are now nine freezers and three dehydrators in operation there. In 1965, four completely new processing plants were built. Several other increased their capacity. Storage capacity in that same year more than doubled from an estimated 3,500,000 cwt. to 7,200,000 cwt.

Disposition reports from the Washington State Potato Committee reflect the increased emphasis being placed on processing as shown in table 1.

The importance of these processing plants to the Washington potato industry cannot be overemphasized. First, they give the industry an opportunity to upgrade the quality of the fresh potatoes shipped by providing an expanding processing outlet for below standard potatoes. Second, they should stabilize prices to growers and reduce erratic shifts in planted acreage. Third, and perhaps most important, a healthy processing segment should enable Washington's potato industry to capitalize on the expanding market for products with built-in conveniences, which one author has predicted will utilize more than half the potatoes used for food by 1970.[3]

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[2]Data on yields obtained from Crop Production, U.S. Department of Agriculture, Statistical Reporting Service, July 11, 1966, and Annual Crop Production Reports, Bureau of Reclamation.

[3]Will Simmons. An Economic Study of the U.S. Potato Industry, U.S. Dept. Agr., Agr. Econ. Rpt. No. 6, March 1962.

TABLE 1.--Potatoes frozen and dehydrated in Washington

Year	Freezing	Dehydration
	1,000 cwt.	1,000 cwt.
1954-55	55.8	--
1955-56	133.1	--
1956-57	270.6	--
1957-58	297.5	--
1958-59	510.5	--
1959-60	508.9	--
1960-61	1,483.9	--
1961-62	1,610.7	--
1962-63	1,962.9	--
1963-64	1,884.2	--
1964-65	2,204.1	93.8
1965-66	7,187.4	1,941.8

Source: Final Potato Disposition Reports, State of Washington Potato Committee, 111 Pierce Avenue, Yakima, Wash. Figures for 1954-55 through 1956-57 converted to 1,000 cwt. equivalents from carlot basis, 360 cwt. per car. Figures for 1957-58 through 1963-64 converted to 1,000 cwt. equivalents from carlot basis, 400 cwt. per car.

In one sense increased potato processing and storage facilities were bound to come to Washington. High yields in the Columbia Basin meant a potential source of raw product at a price at least no higher than that in any other area. To a food processor raw product cost is only one of several costs that affect his profit margin. And, since he cannot sell his product for more than his competitor, he must constantly attempt to reduce costs in order to make his margin.

When Washington potatoes are dug they are about as far away from Eastern population centers as potatoes can be. This means 5 to 7 days en route to market and possible loss of condition. In addition, it usually makes economic sense to ship a processed, non-perishable product great distances to market rather than the fresh product.

Given a brief look at the past and the present, what might be the future of Washington's potato industry? The Simmons study above emphasized a point that has relevance to Washington's future in potatoes. He said, "In general, production has moved toward areas enjoying a cost advantage in production and marketing, or having less attractive alternative production opportunities; or to areas which because of soil and climate are well suited to the production of certain kinds of potatoes."

A less refined way of saying this is that land tends to move towards its highest and best use. So just as potato production moved from West to East within Washington, so may it move increasingly from East to West within the United States. Land in the Columbia Basin is available. One report estimates that when the Basin project is completed, "if farmers practiced a 5-year crop rotation, a potato potential of over 200,000 acres per year could be realized."[4]

A recent study at Washington State University compared net incomes of a median sized farm in the Columbia Basin.[5] Results indicated that net income on the synthesized farm (a family farm) was increased more than $8,000 when 37.1 acres of potatoes were included in the farm enterprises. Expansion of these results to the entire irrigated Columbia Basin indicated that over 100,000 acres of potatoes would be economically feasible.

Some investors and farmers, however, cannot and are not waiting for the Bureau of Reclamation to bring new acres under irrigation. A recent report indicates that a 25,000-acre tract of land is being privately developed for potato production in the Horse Heaven Hills area near Pasco, Wash. Similar reports are coming out of Idaho indicating that water is being pumped from 50 to 800 feet up from the Snake River through 18- to 30-inch pipes to irrigate additional acreage.[6] Howard Roylance, Extension Agronomist at the University of Idaho, was recently quoted as saying that private enterprise has been responsible for most of this development.[7]

Part of the reason private capital is accelerating the development in these areas is that the returns to investments in irrigation systems of these types are often quite high. A study at Washington State University recently showed that a deep well irrigation system which added 12 inches of water to wheat in

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[4]R. Kunkle and D. B. Bakes. Potatoes In The Columbia Basin of Washington. Amer. Potato J., pp. 369-376, December 1965.

[5]E. E. Weeks and R. G. Mueller. Sugar Beets, Potatoes and Changes in Net Farm Income On A Columbia Basin, Washington Farm, paper presented at the 1966 Western Farm Econ. Assoc. Ann. Meeting, Los Angeles, Calif., August 15-17, 1966.

[6]Wilson Kellogg. Idaho Expands Potato Potential. The Potato and Onion World. Tabb's Market Service, Inc., Chicago, Ill., May 1966.

[7]Spokane Daily Chronicle. June 30, 1966.

eastern Washington returned 25 percent per year to the additional investment in well, pump, and sprinkler system.[8] There's not much question about the "soundness" of an investment which will pay out in 4 years!

One reasonable interpretation of increased use of private capital in these regions is that the Bureau of Reclamation has proved the economic feasibility of developing and irrigating these lands. Once proved, private capital is then attracted since it does not come under the time and size-of-farm restrictions imposed by the Bureau of Reclamation. In these terms then, the Bureau's activities have proved to be a rather large demonstration plot from which private investors and land developers can draw ideas and make independent investment decisions.

In summary, the potato industry of Washington has been one of development and change. Its present status would indicate that it is still dynamic and still developing. Its future, although uncertain, seems very promising. Research is under way with industry, and University support which could lead to further advances in an already favorable yield picture. Private investors will surely hasten the day when Washington's potato industry finds its "place in the sun."

A CHALLENGE TO PROCESSING AND THE WEST--26.5 MILLION PEOPLE AT OUR DOORSTEP

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Three years ago, Long Island was host to the 13th Annual Potato Utilization Conference, held in conjunction with the 50th convention of the Potato Association of America, in my home town of Riverhead. That week left us with a warm feeling for our guests. Those of us who served on the committee felt, too, that we were richly repaid for our efforts by the success of the meetings and the many kind comments on Long Island hospitality.

I'm sure this Conference has been equally productive of timely, helpful information contributed by potato scientists and

[8] Clifton Perryman and others. Deep Well Irrigation of Grain on Summer Fallow Farms of Eastern Washington, E.M. 2617 March 1966.

industry leaders. It is said that Western hospitality is legendary. I know now it is a living legend, as open-hearted and generous today as in frontier times.

I bring warmest greetings and best wishes from the potato people of Long Island. In their behalf, I congratulate the State of Colorado and this University for bringing the conference to Fort Collins. Everyone in the potato business owes a debt of gratitude to the men responsible for this yearly meeting of minds. I refer to men like Kris Bemis, who aptly has been called the founding father of the Conference; to Bob Treadway, who has helped to make it the national--even international--forum it is today; to Dr. Dick Sawyer, who represents the research scientists who use it to give us the benefit of their discoveries.

The title of my talk is a bit cumbersome and may appear disjointed. I speak as a plain, practical potatoman--one who has been in the business as a packer, shipper, and marketer for the better part of 30 years. I'm not here to offer any cure-alls for the obvious ills of the potato trades. If I had such a panacea, I'd be doing something about the present market. And if at times I seem critical, please forgive me. I shall at least attempt to be constructive.

Very candidly, I'm here to state that the East, the oldest and the original potato-growing region in the United States, will be in the potato business for many, many years to come. And when I say the East, I do not mean Maine alone. I refer particularly to Long Island, but also to upstate New York, Pennsylvania, and most of the other States and areas in the Northeast where potatoes are grown.

The past several years have brought developments that seem to indicate that certain Western growing areas have virtually written off their Eastern counterparts, with the possible exception of Maine, as major competitive factors in the potato market. We in the East sincerely believe some of these developments unwise, and that is putting it mildly. We believe that if they continue unchecked, you and we as growers and marketers will suffer.

We frankly think the West has again gone wild and woolly, this time in the spectacular expansion of potato acreage in Idaho and other States far removed from mass markets. We seriously doubt that it makes good economic sense to put all your eggs--pardon me, all your potatoes--in the processing basket. We are positive it is bad business to overplant so heavily that bad weather--drought, flood or frost--is the only possible salvation.

We do not believe any region or State can achieve a monopoly in the production of a food crop so widely grown throughout the Nation and the Western world, and so adaptable to varied soils and climates. Forgive me if I give voice to the suspicion that many Western producers are intoxicated by past successes in the fresh market and present visions of unlimited markets through processing.

Could it also be that too much heed has been paid to the former flaws and failings of the East, and too little thought has been given to the basic, bedrock strength of its production and distribution systems? I think it is a law of physics--and it is certainly the rule in politics and economics--that every force provokes a counterforce. That is what has been happening in the potato business.

In the years following World War II, the West produced better potatoes and did a more effective job of grading, packaging, marketing, and advertising. Idaho especially achieved new highs of consumer preference and product identification for its fine Russet Burbanks. Idahoes and other Western spuds were found in virtually every American market, including those of the East.

It took some years to awaken the East to the significance of this trans-continental movement. We were set in our ways and slow to change. We grew the same old varieties, graded, and packed them pretty much as our fathers and grandfathers did before us. But finally came the realization that we were slowly but surely losing our own markets.

I do not need to tell you the past decade has been one of tremendous change in the potato business, and nowhere is improvement more in evidence than in the East. The counterforce is in operation. Competent and competitive, the Eastern potato industry is again fit and full of fight.

You know what Maine, our Eastern giant, has accomplished, in growing better table stock and seed, in processing, in promoting, and in export. Definitely, Maine is on the move. You may be less aware of the great strides made by other Eastern growing sections, Long Island included. Let me tell you about Long Island.

Geography and climate make Long Island a natural for growing potatoes. We have manifest God-given advantages in level, stone-free, fast draining soils, in a long, frost-free growing season, and in rainfall that over the years has averaged over 45 inches annually. Long Island growers are as efficient as any in the country, as evidenced by the highest per acre yields in the East and the second highest in the Nation. In holding tonnage at the level of 10 years ago, despite a 25 percent reduction in acreage, they

have made optimum use of improved varieties, foundation seed, multirow equipment, spray irrigation, and specialized fertilizers.

Do you realize that Long Island has a larger proportion of modern storages per acre than any other area and is building more this year--over 40 at present count. And the use of sprout inhibitors to extend the marketable life of late crop potatoes is standard practice today.

Varietal shifts, expanded storage, and inhibitors have added 5 months to our marketing period, enabling us to maintain continuity of supply to do a more effective merchandising job. A decade ago, the great bulk of our tonnage was moved by January 1. Now we are selling potatoes until June. This is an 11-month marketing period. But because of our mild climate, we still have the big advantage of marketing fresh potatoes directly from the field from the middle of July until early November. Long Island also has made momentous advances in grading, sizing, washing, and packaging. By far the larger portion of our fresh market movement is to consumers; we package 5s to 20s, in both paper and poly. And again, the greater portion are washed. But perhaps Long Island's greatest asset and advantage is our close proximity to the Nation's richest market--the 26.5 million people at our doorstep, all within a 150-mile radius of Riverhead.

Our modernized marketing program is succeeding because of many reasons. One is our ability to be flexible, to give our customers what they want, when they want it, and how they want it. It is not unusual for a customer to call in an order as late as 4 or 5 o'clock in the afternoon and have potatoes in his warehouse for distribution the following morning. Remember, too, that if competitive circumstances compel, our delivered price in this market may be less than the freight tariff alone of potatoes shipped several thousand miles from the West.

While the Long Island industry is geared to the fresh market, we are not foolishly antagnostic to processing. We realize the popular demand for processed potato foods has reversed the downward trend of national consumption and is now the springboard of a prospering export business. We are aware that processing has been, up to this time, of more help than harm to those areas that produce largely for fresh outlets.

Recalling Chamber of Commerce influences that tended to obscure the facts at prior conferences, I would not have you believe that Long Island, or any other Eastern growing area, has solved all problems and resolved all questions. We on the Island appreciate that our mainstay, round varieties fall short of the ideal, even though they yield well, look good, and boil, fry, and

mash satisfactorily. We are also raising some pretty fair bakers, but in some respects they fall short of Russet quality in the West. We must further improve our pack, particularly as to sizing.

But thanks to an aggressive research program and the progressive spirit of our growers and packers, we are gradually finding the answers. Here and now, I predict that we shall continue to produce good potatoes for the fresh market for a century to come, notwithstanding population explosions, housing booms, and six-lane expressways.

How much better it would be for our entire industry--east and west--north and south--if all States and areas would put on the brakes and plant within USDA acreage goals. Thus we would make a conscientious effort to achieve a crop more evenly balanced between production and consumption to the certain profit of producers, shippers, and all others who earn their livelihood from growing and handling potatoes.

We in the East have too long been on the defensive. We have passively watched the year-by-year expansion of acreage in the Western States where there are virtually no markets. We have noted in the recent marketing experiences of Idaho, and even California, signs that the balloon can burst, if inflated much more.

So we are taking the offensive. We shall grow better potatoes, package them more attractively, market them more militantly. We shall plug and promote fresh at every opportunity, and take full advantage of the growing consumer rebellion against processed and synthesized foods.

We shall have more to say through public communications media, through such organizations as the Long Island Agricultural Marketing Association, to maintain and improve our position in this industry. The day of status quo is over. This is our warning and challenge to processing and the West.

A NEW APPROACH TO THE STUDY OF BROWNING IN POTATO CHIPS

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According to current theories, nonenzymic browning results from the interaction of amino compounds with reducing sugars. Various model systems have been set up to study these reactions since the first model systems were reported by Maillard in 1912.[1] A recent review of work in this field was published by Reynolds in 1963.[2] We shall describe a relatively simple technique, which closely approaches the conditions encountered when potato chips are fried.

The present scheme grew out of work done under contract between our Laboratory and a Cornell group.[3] About the same time, a group of Australians[4] were studying the extracts of browned, freeze-dried apricots. These extracts were analyzed by elution chromatography on ion-exchange columns. Intermediate reactants between amino acids and sugars produced ninhydrin-active peaks similar to those produced by the amino acids themselves. However, the resulting picture was quite complicated in that many overlapping peaks were found and the ion-exchange procedure used was not standard. Dr. Fitzpatrick of our laboratory found this to be quite true when he tried to apply the procedure to potatoes.

In the work at Cornell, filter paper disks were dipped in solutions of various reactants and then fried in deep fat. The results were followed by the development of color in the paper. No knowledge was obtained as to the intermediates in the reaction chain.

At present we are using filter paper disks which fit the ion-exchange columns of an amino acid analyzer. The disks are treated with measured quantities of reactants, in solution, and then allowed to dry. The disks are then fried in deep fat and the fat removed with carbon tetrachloride. The washed disks are put in the ion-exchange columns on top of the resin bed and run with the usual buffer and temperature sequence. With each amino

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[1] L. C. Maillard. Compt. rend. 154: 66, 1912.

[2] T. M. Reynolds. Advances in Food Research 12: 1-52, 1963.

[3] R. S. Shallenberger, Ora Smith, and R. H. Treadway. J. Agr. Food Chem. 7: 274-277, 1959.

[4] D. L. Ingles and T. M. Reynolds. Australian J. Chem. 11: 575-580, 1958.

acid-sugar pair, depending on the particular amino acid-sugar combination and the time and temperature of heating, varying numbers of peaks are recorded. (Some reaction even occurs in samples not heated in fat but allowed to stand at room temperature.) In general, one or more fairly large peaks are found in addition to the one due to the amino acid itself. These, we think, are major intermediates.

The paper disks are allowed to dry on a clean, water-repellent surface such as plastic wrap. The amino acids and sugars then remain on the paper disks and are not transferred to the support. The solutions have been applied with a Hamilton gas-tight syringe fitted with a repeating dispenser. Each solution is allowed to air-dry before the next is added. More than one sample can be added to the ion-exchange column during each run, if "windows" can be found at suitable intervals where the peaks won't interfere with each other.

So far, the work has been mainly exploratory. Glucose has been used as the sugar component in most cases. In general, the amount of amino acid left decreased rapidly at first and then more slowly as heating progressed. The concentration of other ninhydrin-active compounds, which appeared, also varied with time of heating. With most of the amino acids, a peak, thought to be due to an intermediate, began to increase from zero time, reached a maximum size, and then decreased to a low value. In the case of valine, two major intermediates appeared, one reaching a maximum before the other, but both showed similar changes with time of heating. Equal quantities of isoleucine and glucose were tested at two levels and the changes were similar in both cases. Sucrose and fructose were tested with leucine as well as glucose. The residual leucine was about the same after about 6 hours at 103°C. But nothing similar to the major intermediate found with glucose appeared in the case of fructose or sucrose. And the curves relating time of heating to residual leucine had slightly different shapes for the three sugars.

The method described here has a large field of possible use. Not only would it be useful for checking the reactions involved in the frying of chips but also for various other storage, dehydration, and frying problems encountered in food processing. The intermediates very likely can be isolated and studied further in a similar way. If conditions can be found to break the reaction chain at any point, excess browning can be inhibited. Storage can be studied under controlled conditions of time, temperature, and moisture content. The moisture content range can be within the range normally encountered in practice. Most of the previous model systems have used the reagents in solution, a condition not met with normally, in the case of cooked or dehydrated foods.

HOW TO MEASURE SMELL

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A baked potato is a good example of the many physiological and psychological factors that are associated with flavor. The brown crisp skin, the pearly appearance of the interior, the mealy texture, the steam that exits when it is first slit, even the shape and color--all are part of the appeal of a baked potato. A bright red baked potato shaped like a corkscrew would not "taste" the same as the characteristic brown tuber we know. So that all of our senses and some "non-senses" such as memory, custom, surrounding, all affect flavor. Some of these factors can be measured; some cannot.

The easy ones to measure are those which are judged by the physical senses--touch, sound, and sight. For example, one can measure texture with various shear-presses, texture-meters, etc.; and it is possible to accurately measure and express in numbers both the light reflected from and transmitted through a substance and the percentages of various wavelengths in this light. Although sound is not usually associated with flavor, it is common to describe a high quality apple as "crunchy," a word that incorporates both sound and texture. This sound, like other physical senses, can be measured, amplified, and recorded. We also have the telescope and microscope to amplify sight and we have sensitive microphones that extend our hearing threshold. Photographs and recordings can bring back sights and sounds. We cannot, however, adequately measure flavor, either qualitatively or quantitatively--or even tell what it is, nor can we amplify it with the aid of instruments.

An increasing amount of purchasing today is based on specifications. Anyone who has supplied foodstuffs on defense contracts knows how complex some of these specifications have become. They include requirements for moisture, particle size, density, limitations on various additives, and others. All of these are expressed in numbers--either maximum or minimum--and appropriate analytical methods are usually given. However, when it comes to flavor, these specifications resort to words such as "characteristic," "typical," and "pungent." No numbers are used and no analytical methods are given--primarily because there are none.

One authority has estimated that about 80 percent of flavor of a foodstuff comes from its odor. We have all heard if one holds

his nose, an apple and onion taste the same. With the entry of gas chromatography into the field of odor analysis, many articles appeared on the wonders of the "electronic nose" and the new field of odor analysis. Hope was expressed that it would now be possible to measure flavor and odor quantitatively. An article in the June 1966 issue of the Scientific American magazine is typical. It began, "As recently as 1950 perfumes were graded by the noses of connoisseurs and wines were judged by the palates of wine tasters. Even chemists occasionally relied on taste and smell in some of their procedures. Today, these arts have been outmoded by the gas chromatograph."

Alas, would that this were true. But it still looks as though professional perfume sniffers and wine tasters will retain their jobs for many more years. Those who work on flavor at the U.S. Department of Agriculture, are well aware of both the uses and the limitations of gas chromatography. The first paper published on the use of gas chromatography in the field of flavor research, "Gas Chromatography--A New Method for the Separation and Identification of Volatile Materials in Foods," was written by Keene, Dimick, and Joseph Corse of our laboratory in 1956. We have continued to maintain an active and aggressive program in instrumentation in flavor research. One of the most fertile techniques has been the coupling of gas chromatography and mass spectrometry. The information provided by retention time in gas chromatography is inadequate for proper identification of many compounds. Mass spectrometry on the other hand gives much valuable information on the structure of various compounds as they emerge from the chromatographic column.

Our laboratory has not neglected the fact that flavor is essentially a physiological response rather than a chemical one. A recent paper by D. G. Guadagni and coworkers, in which a panel of 25 judges in effect "competed" with a gas chromatograph to see which could detect and characterize the odor of Delicious apples showed that the gas chromatograph could barely detect compounds which the human nose found to be strongly characteristic of apple odors. On the other hand, some compounds that produced no response from the panel produced a strong signal from the chromatograph detector.

Many people have speculated on why some things smell bad and some smell good. A musician can look at a music score and predict that the resulting harmonies will be pleasing. Is it possible that similar predictions can be made by looking at the structure of a chemical compound? The Roman philosopher Lucretius wrote in 50 BC that "Substances that agreeably titillate the nose are compounds of smooth, round atoms. Those that seem bitter and harsh are more tightly compacted of hooked particles and

accordingly tear their way into our senses and rend our bodies by their inroads." Dr. John Amoore of our laboratory has joined forces with Lucretius, albeit a little late, with his intriguing stereochemical theory. In effect, Dr. Amoore states that the characteristic smell of organic compounds is determined by their shape and size. For example, 21 different compounds that have the odor of camphor have no common denominator of chemical class--that is, these 21 include aldehydes, alcohols, acids, ketones and others. The only characteristics they have in common, besides the odor of camphor are their closely similar size and shape.

Roy Teranishi of our laboratory has speculated on the role of the flavor chemist of the future. Many textile dyes used by man were primarily of vegetable origin. These have all been replaced by dye chemistry which now provides colors and hues undreamed of in nature. Dr. Teranishi predicts that the flavor chemist, with increasing insight into the structural and spatial relations of molecules, will be able to produce tailormade flavors that will pamper our palates with now unimagined flavor delights. When that day comes we may hope to add to the many diverse products which now flow from the once humble potato.

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